

EXCLUSIVE: HOW STALIN COPIED THE B-29

AIR & SPACE

Smithsonian

MARCH 2001

THUNDER in the Alps

Why the Swiss aren't neutral about their air force

FLUTTER:
Bad Vibrations

PAGE 36

\$3.95 U.S./\$4.95 Canada



Air & Space/Smithsonian Gives You New Ways of Looking at the United States... **and your state and city!**

Now, Air & Space/Smithsonian magazine offers you a unique opportunity to see the world from an entirely new perspective – in all its true colors – in a stunning new collection of posters made available to our readers through a special arrangement with M-SAT Editions.

Observation satellites orbiting 440 miles above Earth captured these images with amazing precision, at a level of detail down to 100 feet. You'll marvel at the clarity of landscapes both natural and manmade, from tree-lined ridges to farm-field mosaics. Trace the course of rivers and the development of cities. And gain a new appreciation for the geological and cultural forces that have shaped and defined the places where we work and live.

Each Poster is printed on high-quality heavy paper, and is more than 2 1/2 times the weight of standard posters. They are then coated with a UV-protective layer to prevent image fading and preserve and enhance the natural coloration.

So improve your outlook on the world – and the walls of your home or office – with satellite posters exclusively from Air & Space/Smithsonian magazine.



the United States of America from space

Presented by

AIR & SPACE

Magazine

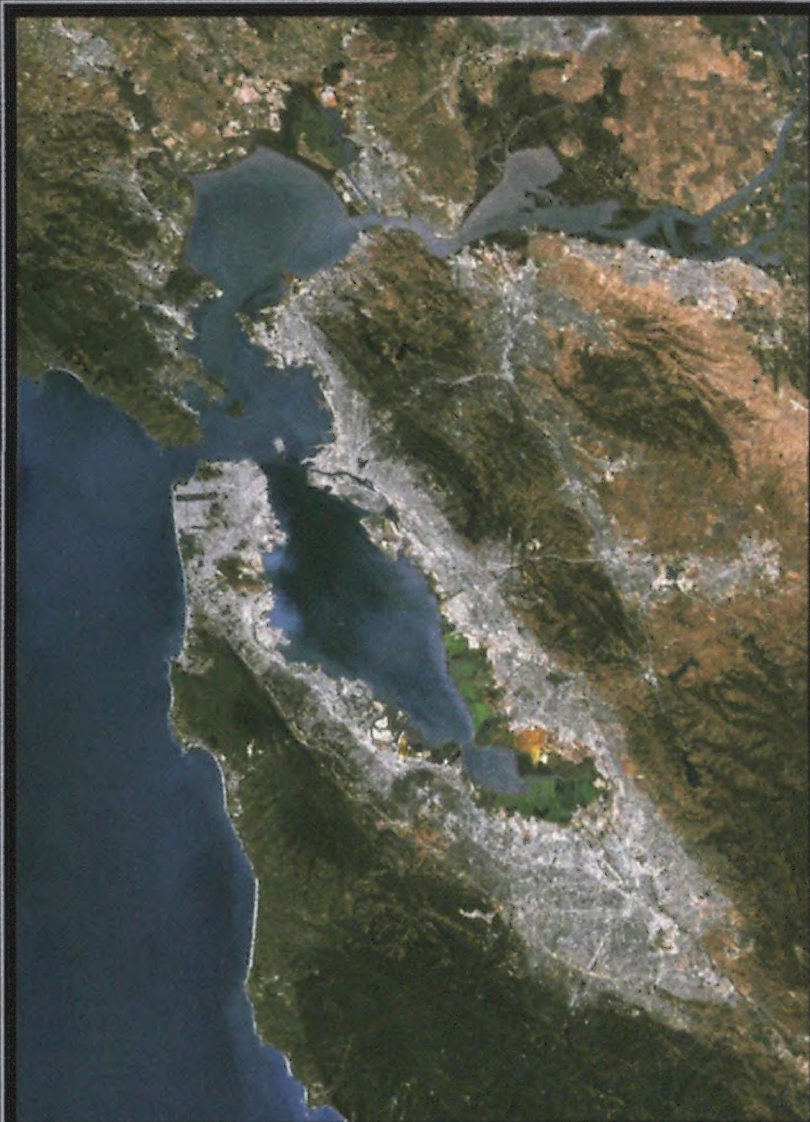


The U.S. From Space – 28" x 40" \$29.95

California From Space



California 28"x40" : \$29.95



SAN FRANCISCO - OAKLAND FROM SPACE

San Francisco - Oakland 28"x40" : \$29.95

Air & Space/Smithsonian Magazine Reader Offer

Your choice: \$29.95/\$24.95 per poster or any 3 for \$69.95.

Mail order to: Air & Space/Smithsonian Magazine, 901 D Street, SW, 10th Floor, Washington, DC 20024. Phone: 1-800-824-5974 toll-free to leave a recorded message with credit card and mailing information. Please include poster codes with your order.

Fax credit card information to: 202-287-3163.

Reference Codes

Posters available for the 20 states and 25 cities with the largest populations.

28" x 40"
Price: \$29.95

20" x 28"
Price: \$24.95

States

Georgia	GA
Indiana	IN
Massachusetts	MA
Maryland	MD
Minnesota	MN
Missouri	MO
Tennessee	TN
Washington	WA
Wisconsin	WI

Cities

Atlanta	ATL
Baltimore	BAL
Cincinnati	CIN
Denver	DEN
Portland (OR)	POR
San Diego	SAD
St. Louis	SLO
Kansas City	KAN
Minneapolis/SP	MSP
Milwaukee	MIL
New Orleans	NOR
Phoenix	PHO
Pittsburgh	PIT
Seattle	SEA

States	Cities
California	CA
Florida	FL
Illinois	IL
Michigan	MI
North Carolina	NC
New Jersey	NJ
New York	NY
Ohio	OH
Pennsylvania	PA
Texas	TX
Virginia	VA

AUS
WOR
EUR

The U.S.A from Space
The World from Space
Western Europe from Space

Natural Areas

Grand Canyon	GCA
Chesapeake Bay	CHB
Mississippi Delta	MDE
Great Salt Lake	GSL

SETS		Reference	Item Price	Price
First Set			\$69.95	
Second Set			\$69.95	
SINGLE POSTERS	Quantity	Reference	Item Price	Price
Please allow 3-4 weeks for delivery Posters shipped rolled in heavy mailing tube			Shipping & Handling	\$3.00
			Total Order	

☐ Check or money order enclosed (Make check payable to: Air & Space/Smithsonian)
☐ Discover ☐ Mastercard ☐ American Express ☐ VISA

Card # _____

Signature _____ Card Exp. Date _____

Mailing Address (please print):

Name _____

Address _____

City _____ State _____ Zip _____

Visit our web site to see all 52 poster images - www.airspacemag.com



18

AIR & SPACE

Smithsonian

February/March 2001
Volume 15 • Number 6

FEATURES

- 18 Don't Mess With Switzerland** by Carl Posey
Photographs by Katsuhiko Tokunaga
Small country. Big attitude. With three new squadrons of F/A-18 Hornets to back it up.
- 28 Terra Cognita** by Tony Reichhardt
A new armada of Earth-observing satellites shows the home planet like you've never seen it before.
- 36 The Hammer** by Peter Garrison *Illustrations by John MacNeill*
"Flutter"—an oddly gentle name for a phenomenon that could mean disaster for an airplane.
- 44 Restoration: Desperate Journey** by Douglas Hinton
Introducing a new feature: Reports of projects to restore historic aircraft, like this Junkers Ju 88 bomber, pulled last year from a Norwegian lake.
- 46 Baikonur** by John Sotham
From the site where Sputnik and Gagarin took off, Russians launch among the ruins.
- 52 Commentary: Metric Mayhem**
by Michael Milstein
Is the United States finally crawling toward the metric system? Sure it is. Inch by inch.
- 54 High Tension** by James R. Chiles
Photographs by Jeffrey Brown
Snap. Crackle. Pop. The sounds helicopter linemen don't want to hear.
- 62 What Were They Thinking?** by Phil Scott
Turn-of-the-century inventors of flying machines were anything but single-minded.
- 68 Made in the U.S.S.R.** by Von Hardesty
The first Soviet strategic bomber bears an amazing resemblance to the Boeing B-29. Even more amazing, when you know the story.



54



46



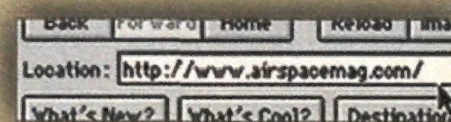
68



Cover:
Katsuhiko Tokunaga framed the F-5Es of the Patrouille Suisse against Switzerland's most famous peak. There's more than one way to summit the Matterhorn.

DEPARTMENTS

- | | | | |
|----|--------------------------|----|----------------------|
| 4 | Viewport | 80 | Sightings |
| 5 | Letters | 82 | Reviews & Previews |
| 8 | Soundings | 86 | Credits |
| 12 | In the Museum | 86 | Calendar |
| 14 | Above & Beyond | 87 | On the Web Site |
| 16 | Oldies & Oddities | 87 | Forecast |
| 43 | The Smithsonian Traveler | 88 | Moments & Milestones |



Three out of every four
Tempur-Pedic owners
recommend this bed to
friends and relatives

Theirs...

*Fancy on
the outside.*

Ours...

*Miracle
on the inside.*

It's what's inside that counts...

SWEDISH SCIENTISTS WORK UNDERCOVER TO CREATE THIS WEIGHTLESS SLEEP SYSTEM!

They use NASA's anti-G-force research to invent a marvel of molecular physics...

Tempur-Pedic's phenomenal Swedish bed is changing the way Americans sleep. Our amazing bed is the future. Innersprings and air-beds are the past.

Other mattresses are fancy on the outside. Ours is a miracle on the inside! Billions of viscoelastic MEMORY CELLS work as molecular springs (see cut-away photo) to conform precisely to your body.

We promise super high-quality sleep!

The thick pad that covers other mattresses keeps their steel springs inside, but creates a hammock effect outside. This can actually cause pressure points. That's why Tempur-Pedic drastically reduces tossing and turning!

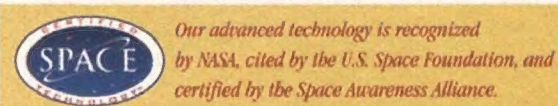
Adjusts to fit you and your spouse.

Our exclusive Tempur® material uses body mass and temperature to selectively adjust to your exact shape

and weight. This sleep matrix gives you total support. Its microporous structure is self-ventilating. You also get our new AirFlow™ system.

Works naturally...automatically.

The Tempur-Pedic bed utilizes no electricity, no compressed air, no heated water. Instead, it uses natural



principles of physics to give you the energizing "lift" of weightless sleep. There are no settings or controls to adjust...no heaters, motors, or air pumps to break. You do nothing but lie down on it!

The press is giving us rave reviews!

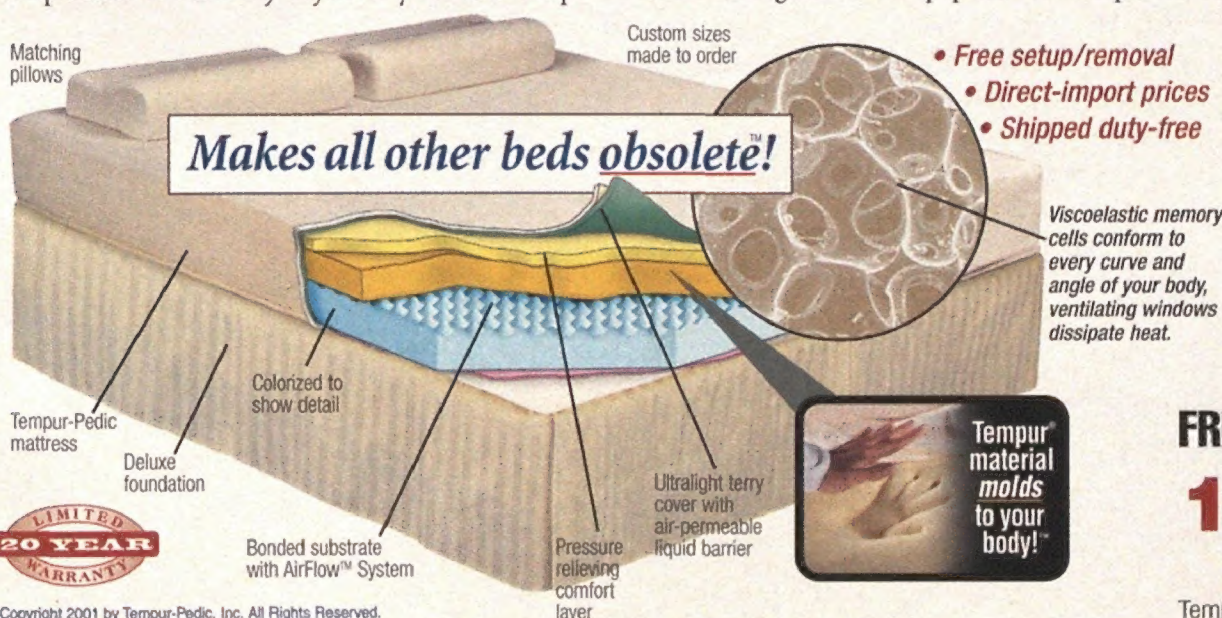
TV, radio, magazines, newspapers, medical publica-

tions...our high-tech bed is winning wide acclaim. DATELINE NBC told all America about Tempur-Pedic. So did Lou Dobbs on CNN's *Business Unusual*, and CNBC's *Power Lunch*. NBC's *Today Show*, Associated Press, Discovery Channel, and others have also featured our breakthrough sleep technology.

Try it at our risk for 3 months!

We'll set up a new Tempur-Pedic bed, in your bedroom...even remove the old bedding...and give you 3 full months to sleep on it. If you don't love it, we'll pick it up—at our expense—no questions asked!

Thousands of health professionals say 'Yes!' Our owners love the feeling of WEIGHTLESS SLEEP and the way Tempur-Pedic helps ease aches, pains, back problems. Thousands of sleep clinics and health professionals recommend our SWEDISH SLEEP SYSTEM!



- Free setup/removal
- Direct-import prices
- Shipped duty-free

**FREE DEMONSTRATION KIT
is now yours for the asking!**



FREE SAMPLE / FREE VIDEO / FREE INFO

1-800-720-7317

FAX us at 1-859-259-9843

Tempur-Pedic, Inc., 1713 Jaggie Fox Way, Lexington, KY 40511

Detective Work

When Edward York had to land his B-25 following the Doolittle raid on Tokyo, the field at Vladivostok in the U.S.S.R. looked like a safe bet. Heeding the siren call of Vladivostok and thinking of the Soviets as allies, three B-29 pilots landed there in 1944. Although the crews were released eventually, the Soviets refused to return any U.S. aircraft, and their fate was lost in the cloud of the cold war.

We later learned that Stalin ordered Andrei Tupolev to copy the design of the B-29 in a crash program of reverse engineering. The resulting clone, the Tu-4, gave the Soviet Union a credible strategic bomber at the dawn of the cold war.

The mystery of the interned B-29s caught the attention of Von Hardesty, a Museum curator and specialist in Soviet air power. On a trip to Moscow in 1991, Hardesty met with Leonid Kerber, a close associate of Tupolev on the Tu-4 project. The meeting spurred Hardesty to translate Kerber's memoir: *Stalin's Aviation Gulag* (Smithsonian Institution Press, 1996), which brought to U.S. readers the first insider's account of the top-secret Tu-4 project.

But many questions were left unanswered, so Hardesty recruited Russian historians and museum specialists to help uncover the full story of the B-29 and Tu-4 bombers. One key figure, Dmitry Sobolev, had spent a year with us as a research fellow. Vladimir Rigmant, director of the Tupolev Museum, opened the archives of the Tupolev Design Bureau. Interviews added to the records, and the elusive facts about the B-29s slowly emerged.

More revelations brought the story into sharper focus. For example, it was

learned that *Ramp Tramp*, one of the interned B-29s, had flown in Russia for nearly a decade until it was scrapped in 1954. The research also turned up some exceptional photographs that had never been seen in the West, and these appear for the first time in Hardesty's feature article, "Made in the U.S.S.R." (page 68).

Further detective work revealed that a plaque placed in the cockpit of the *General H.H. Arnold Special* by Boeing workers at Wichita in 1942 had not only survived but was in safekeeping in Moscow. Kerber had given the plaque to Maximilian Saukke, a friend and aviation writer, and Saukke still has it.

The intrepid Russian investigators even discovered new information on the probable fate of Edward York's B-25: It had survived the war only to end up in a field of abandoned military aircraft on a grass strip at Vladivostok. It was last seen in the late 1940s, when it apparently was destroyed in a fire, perhaps set accidentally by children who had made a playground out of the surplus aircraft. We're still waiting for confirmation of this story.

This is just one program in which the Museum is collaborating with Russian scholars. With the cold war over, we must share data on our history so we can continue to solve some of the mysteries of that era. When the Museum committed itself to enable research fellows from Russia to visit us in the late 1980s, we were like Edward York when he landed his bomber: We couldn't foresee the outcome. It turns out to have been money well spent.

—J.R. Dailey is the director of the National Air and Space Museum.

Secretary of the Smithsonian Institution	Lawrence M. Small
Editor	George C. Larson
Executive Editor	Linda Musser Shiner
Senior Editor	Patricia Trenner
Senior Associate Editor	Perry Turner
Associate Editors	Eric Adams John Sotham Diane Tedeschi
Consulting Editor	Tony Reichhardt
Photography/Illustration	Caroline Sheen
Graphic Design	Ted Lopez, Eason Associates, Inc.
Production Assistant	Matthew Hale

Contributing Editors:

Roger Bilstein	W. David Lewis
William E. Burrows	Eric Long
Eric Chaisson	Stephen Maran
Tom Crouch	Laurence Marschall
David DeVorkin	Ted Maxwell
Ron Dick	Ron Miller
Beth Dickey	Brian Nicklas
Freeman Dyson	James Oberg
Daniel Ford	Edwards Park
Greg Freiherr	Dominick Pisano
Donald Goldsmith	Robert E. Pollack
George Greenstein	Fred Reed
William Gregory	George Robinson
Dan Hagedorn	Theodore Robinson
R. Cargill Hall	Chad Slattery
Richard Hallion	Marcia Smith
Jim Hansen	Robert W. Smith
Gregg Herken	Jill Tarter
Nick Komons	Steven L. Thompson
Nick Kotz	G.L. Verschuur
Saunders B. Kramer	Stephan Wilkinson

Editorial: (202) 275-1230

e-mail: editors@airspacemag.com

Web site: www.airspacemag.com

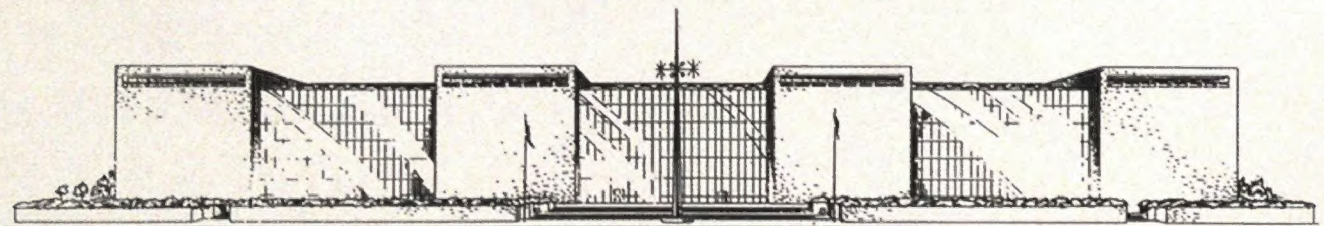
Air & Space/Smithsonian (ISSN 0886-2257) is published bimonthly by the Smithsonian Institution, 900 Jefferson Drive, Washington, DC 20560. ©Smithsonian Institution, 2001. All rights reserved. Reproduction in whole or in part without permission is prohibited. Editorial offices: 700 9th St. NW, 7th Floor, Washington, DC 20001. Circulation and advertising offices: 420 Lexington Ave., New York, NY 10170. Publication agreement No. 1664166.

Subscription Prices: U.S. and possessions: \$22 a year payable in U.S. funds. Canada and all other countries: add \$6.00 (U.S. funds) per year. Eighty-five percent of dues is designated for magazine subscription. Current issue price: \$3.95 (U.S. funds). Back issue price: \$7.00 (U.S. funds). Periodical postage paid at Washington, DC, and additional mailing offices.

Mailing Lists: We sometimes make our subscriber list available to companies that sell goods and services by mail that we believe would interest our readers. If you do not want to receive such mailings, send your current mailing label or exact copy to *Air & Space/Smithsonian*, Mail Preference Service, PO Box 420113, Palm Coast, FL 32142-0113.

Address Changes and Subscription Orders: mail to *Air & Space/Smithsonian*, PO Box 420113, Palm Coast, FL 32142-0113; call 1 (800) 766-2149; outside the U.S., call 1 (904) 445-4662. (Postmaster: Send change of address to *Air & Space/Smithsonian*, PO Box 420113, Palm Coast, FL 32142-0113.)

Printed in the USA



Why Not in Denver?

Locating the expansion of the National Air and Space Museum in the Washington, D.C. area is a critical mistake ("Beginning to Begin," Viewport, Aug./Sept. 2000). The Smithsonian has historically been far less successful than many smaller institutions in getting artifacts and exhibits out into the country at large. A rare opportunity was missed in the planning stages of the Steven Udvar-Hazy Center, as during that time the city of Denver was seeking proposals for developing the former sites of Stapleton International Airport and Lowry Air Force Base. Denver's dry climate is much more suitable for long-term aircraft storage, and a facility there would be much less dependent on expensive climate control systems. Both Denver sites would have offered fewer space constraints and steadier year-round tourist flow. I fear that the Dulles location will cause attendance to fall short of what supporters expect. Airport travelers will face time and luggage constraints, while local visitors will be hampered by almost nonexistent public transportation and worsening traffic in the area. The rush-rush mentality that appears to be taking over this project is never a good sign.

I'm sure the center will be wonderful when completed. My own support, though, will remain limited to a simple, sincere "good luck."

—Anthony Cramer
Fort Collins, Colorado

National Air and Space Museum Director John R. Dailey replies: We are sorry that you are not willing to support our new center because it is located at Dulles. The Udvar-Hazy Center is an integral part of the Smithsonian's National Air and Space Museum, and, as the home for the national collection, it belongs in the nation's capital. Its proximity to the Mall museum will simplify the movement of artifacts between the two centers. This has been anything but a rush-rush project; the staff has been working for more than 17 years to get this facility built.

NASM is, and has been, quite successful at getting artifacts out into the nation. About 20 percent of the aircraft collection (more than are on display in the Mall museum) and a large number of spacecraft are on loan to museums all over the United States (38 in all). NASM has several exhibits touring the country under the auspices

of the Smithsonian Institution Traveling Exhibition Service. Also, a growing number of U.S. museums are becoming affiliates of the Smithsonian Institution. This activity is a major part of our efforts to spread the Smithsonian experience outside the Washington, D.C. area.

Remembering a Pioneer

The picture of the XB-43 on your cover ("Beat Up and Beautiful," Dec. 2000/Jan. 2001) brought back fond memories of a lovely old airplane. As a beginning test pilot back in 1950 I was assigned to Flight Test Operations at Edwards Air Force Base (it was then named Muroc). I had zero hours of jet flying time and had my second jet flight in the XB-43. I later got checked out in the airplane and flew it on quite a few missions. The XB-43 was the first jet bomber built in the United States. There were originally two XB-43s, but one had an engine compressor fail, which damaged the airplane beyond economically feasible repair. The airplane had simple systems and was relatively easy to maintain, so it was kept in use as an engine test airplane and later as a chase and photo chase airplane. We often flew it to 40,000 feet or above to do engine restart tests. There was no cabin pressurization, but our bodies were much younger then. Optically pure glass panels were installed in the nose to allow a photographer to get better pictures. Then Captain Kit Murray, who was the instructor pilot on my first flight in the airplane, flew the airplane back to the Smithsonian. The XB-43 was an honest airplane to fly. It was not fast enough to go into production, but it certainly has a significant place in history. It deserves to be restored and brought out into the light of day instead of being allowed to slowly deteriorate.

—Lt. Col. Fitzhugh Fulton
U.S. Air Force (ret.)
Lancaster, California

Fallout from the Xmas Bombing

Appalling. That senior military leadership arrogantly refused to listen to input from the field and alter tactics at the outset is simply criminal ("The Xmas Bombing," Dec. 2000/Jan. 2001). My 20 years in the Air Force taught me one thing: Seldom is anyone at flag rank expected to assume responsibility for his own foolish decisions. Otherwise, the Commander-in-



Smithsonian Institution

Publisher
Marketing Director

Amy Wilkins
Diane Lowman

Advertising

Northeast
Southeast
Midwest
Detroit
Los Angeles
San Francisco
Research Director
Research Manager

Jeff Diskin, (203) 831-9626
Byron Brown, (770) 998-2889
Dick Opfer, (312) 575-1100
Don Heth, (248) 642-7273
Gary Thompson, (310) 478-3833
Charles Schmuck, (415) 986-1945
Renee Mitchell
Isabella Holazo

Circulation

Vice President,
Consumer Marketing
Circulation Director
Planning Director
Fulfillment Director

Scott I. Rockman
Carolyn Topak
Elizabeth Hopkins
Andrea Sole

Production

Production Manager

Sarah D. Kingsley

Business

Senior Business Manager
Manager
Assistant

David Kefford
Shelia Perry Brannum
Frances Jackson

Assistant to the Publisher Edward J. Hayes

Smithsonian Business Ventures

Chief Executive Officer Gary M. Beer
Executive Assistant Jeanny Kim

Board of Directors

Chairman Anthony Walters
Members: Robert Bailey, Gary Beer, Robert Fri, Thomas Kenney, Adolfo Marzol, Ronald Ruskin, Donald Steiner

Director, National Air and Space Museum
General John R. Dailey USMC (ret.)

Board of Regents

Ex Officio
Chief Justice of the United States
William H. Rehnquist, Chancellor
Vice President of the United States
Richard B. Cheney

Appointed by the President of the Senate

Honorable Thad Cochran
Honorable Bill Frist

Appointed by the Speaker of the House

Honorable Sam Johnson
Honorable Robert Matsui
Honorable Ralph Regula

Appointed by Joint Resolution of Congress

Honorable Howard H. Baker Jr.
Honorable Barber B. Conable Jr.
Dr. Hanna H. Gray
Ms. Anne d'Harnoncourt
Dr. Manuel L. Ibáñez
Dr. Homer A. Neal
Mr. Alan G. Spoon
Mr. Wesley S. Williams Jr.

Chief/Strategic Air Command and several of his staff would have been relieved of command, court-martialed for dereliction of duty, and made to apologize to the families of the men sacrificed due to their stupidity.

—David G. White
Lithia Springs, Georgia

I was dismayed by the caption on the picture on page 87. Since I have not visited the B-52 museum, I cannot be sure that they do not have Senator John McCain's ejection seat on display; however, the seat pictured is clearly an early Weber B-52. As the caption correctly mentions, Senator McCain ejected from an A-4 Skyhawk, so the seat is clearly not his. His seat should be a Douglas Escapac 1-A1 or a later Escapac. The seats are very different in appearance.

Ejection seats are a difficult thing for most historians, especially as many aircraft have gone through several seats over their service lives. One example is the F-104; the various versions had at least six different seats. The A-4 had at least two, and the B-52 had at least four different ejection seats for the early/late and up/down positions (with more variants if you consider the difference between pilot and copilot seats).

—Kevin Coyne,
The Ejection Site
<http://www.bestweb.net/~kcoyne/eject.htm>



LEFT: CHAD LEBEAU; RIGHT: GEOFFREY CLIFFORD

Editors' reply: Several readers recognized the ejection seat in the photograph (right) as a B-52 seat and not the Escapac ejection seat that would have been used in John McCain's A-4 (left). Because the seat was identified by B-52 museum staff as McCain's seat, the author has sent word to museum officials that the identification is incorrect.

Your story makes reference to "low-flying FB-111 fighter-bombers." Although they may have looked similar, there were important technical and philosophical differences between the FB-111s of the Strategic Air Command and the F-111s of

the Tactical Air Command. Only F-111As saw combat in Vietnam. F-111 crews like having their jet referred to as the FB-111 about as much as James Carville likes to be called a Republican.

—Jim Rotramel
Lexington Park, Maryland

Rockets in Motion

In the otherwise excellent article "Mr. Estes Comes to Washington" (In the Museum, Oct./Nov. 2000), the author called the model rocket propelling device an engine. In fact, it is a motor. An engine is a machine that converts energy to mechanical motion, while a motor is something that imparts motion.

—Joey Kalis
Colorado Springs, Colorado

Photographic Memory

As principal investigator on the Mars Climate Orbiter Color Imager (MARCI), I was surprised to read in "Hang a Right at Jupiter" (Dec. 200/Jan. 2001) that "photography wasn't one of the mission's scientific objectives and cameras were left behind as an unnecessary luxury." When I last saw the cameras, a few hours before launch, they were definitely bolted onto the spacecraft! The MARCI was very much a part of the mission's science effort, and would have played an important role in chronicling Martian weather and surface processes.

The piece also states: "Had the spacecraft been carrying a camera during its final approach, it would have been obvious from the photographs of the Martian moons that the craft wasn't where it was supposed to be." The use of MARCI images for optical navigation was considered by mission managers, but rejected. In order to acquire pictures of Mars, the spacecraft would have had to have been rotated so that the camera could see the planet, a maneuver that the engineers in charge of the mission felt was too risky to perform prior to the all-important engine firing for Mars Orbit Insertion.

We proposed that this observation be made about five days before MOI; project management conceded a single set of pictures taken 22 days before MOI, from a distance of 4.5 million kilometers. The result, available at www.msss.com/mars_images/marci/9_99_marci_approach/, is the only "science" datum returned from the entire Mars Surveyor 1998 project.

Observations from locations closer to the planet might have indeed revealed the navigation error, but that error was not apparent in analyses of these images, owing to their very low resolution.

One final note: During the past year, optical navigation was proposed for the Mars 2001 Odyssey mission, scheduled to launch in early April 2001. Mission managers again rejected the idea in favor of the radiometric tracking methods preferred by JPL's navigators.

—Michael C. Malin
Malin Space Science Systems
San Diego, California

Editors' reply: The statement about MCO's cameras was introduced during editing. We regret the error.

Criminal Conduct

I disagree with the notion that airline crashes should not be considered criminal ("Why Airline Crashes Aren't Criminal," Commentary, Dec. 2000/Jan. 2001). While the majority are not, those that can be traced to a company not completing the required inspections or disregarding other Federal Aviation Administration regulations, whether directly causing an accident or not, should be treated as criminal. Such companies are placing the lives of their passengers in jeopardy.

Perhaps the National Transportation Safety Board should conduct two separate investigations, one devoted only to finding the cause of the accident and the other to determine possible criminal acts, as the Judge Advocate General's office does in the Navy. When these investigations are kept separate, involved personnel feel free to talk to the accident investigator, since such testimony cannot be used against them in a criminal case unless they give the investigator false information.

—Wilson McCulley
U.S. Naval Reserve (ret.)
Green Cove Springs, Florida

I do agree that there is too much litigation surrounding accidents, but placing the threshold at "deliberate sabotage" like the Pan Am 103 explosion is unacceptable. What about a maintenance supervisor who pressures the mechanic to install old parts to meet schedules instead of regulations? What about a mechanic who puts in an old part even though the act is against regulations? Would I prosecute? If there was criminal intent, hell yes! Even if no

LETTERS

lives were lost? Hell yes! We can't afford not to. Regulations and laws are there because experience has shown that in all endeavors, people come in second behind profit or gain. If we do not demand compliance and enforcement, then "air safety" is just another phrase full of air and more people die, not less. When I read the argument that "prosecuting those responsible doesn't benefit anyone," I was reminded of a lesson from long ago: What do politicians, lawyers, and prostitutes have in common? Each will assume any position for the right price.

—Russ Chapman
Atascadero, California

Oh That Ozark

I am so happy to see Ozark Air Lines back in the air ("Home Grown," Dec. 2000/Jan. 2001). I well remember flying with them out of St. Louis to Galesburg and then on to Chicago, I believe with a stop in Joplin. I was traveling for General Dynamics and that allowed me to see relatives and take care of farm business near Galesburg.

I would like to see them someday fly a route between Dallas-Fort Worth; Tucson; San Diego; Ontario, California; Santa Barbara; San Luis Obispo; and San Francisco. My wife and I would like to fly

from our home, which is near Ontario, to San Luis Obispo, near our ranch in Cambria.

—Elvin I. Tinkham
Alta Loma, California

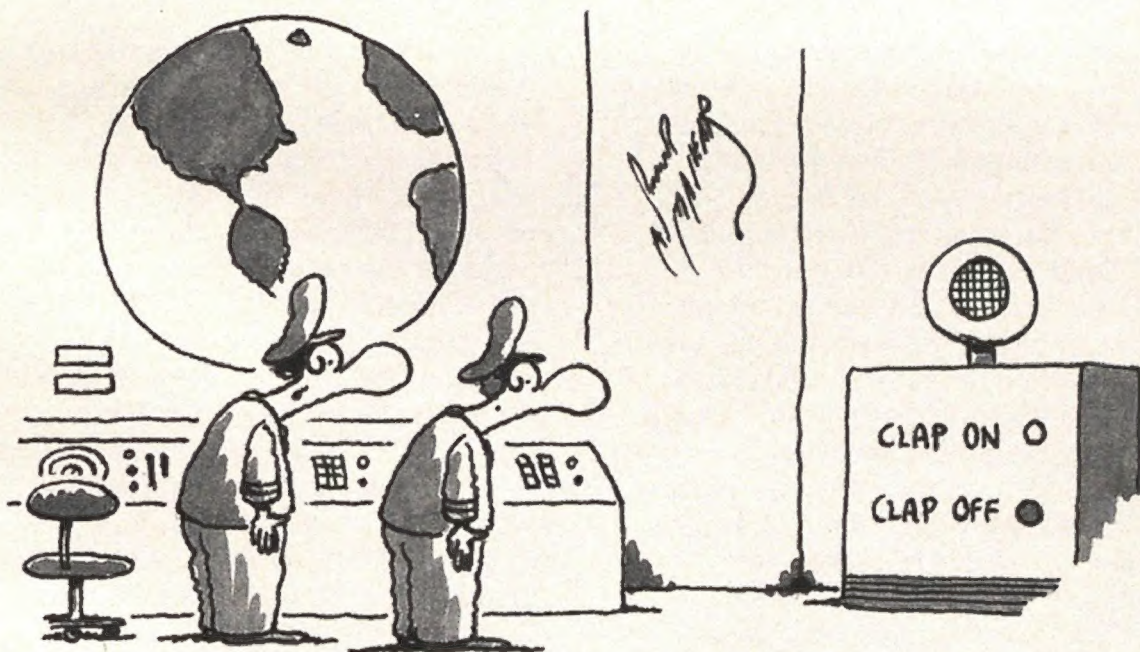
Corrections

Dec. 2000/Jan. 2001 "Beat Up and Beautiful." (1) The Sikorsky JRS-1 was the military version of the twin-engine S-43, not the S-42. (2) The *Enola Gay* was built by the Glenn L. Martin Aircraft company at its Omaha, Nebraska plant, not by Boeing at its Seattle or Wichita plant, as implied.

Write to us at: Letters, Air & Space/ Smithsonian, 750 9th St. NW, 7th Floor, Washington, DC 20001. Please type or print clearly. You must include your full address and daytime phone number. All letters are edited for publication.

Air & Space is not responsible for the return of unsolicited photographs or other materials. We regret that we cannot acknowledge every letter personally.

e-mail editors@airspacemag.com. You must include your full name, mailing address, and daytime phone number.



"I'm not sure about this new missile launch system."

TIME TRAVELER



FX Automatic UTC
3 Time Zones

Exclusively available at:

Geiss & Sons: Greenville, SC (864) 297-6458
Argo & Lehne Jewelers: Upper Arlington, OH (614) 457-626
Reid Vining Jewelers: Little Rock, AR (501) 221-2420

Tutima
German Tradition since 1927



Tutima Chronographs are
official standard equipment
for NATO pilots.

Dosvidaniya, Mir

After months of seesawing—"It's staying up," "It's coming down"—Energia announced last November that the grim economics of the Mir space station dictate its decommissioning. With the International Space Station now staffed, Russia plans to drive the 15-year-old station from orbit later this month or early March. Any parts of the 150-ton outpost that survive incineration in Earth's atmosphere will end up at the bottom of the Pacific Ocean. To the dismay of its former inhabitants and some museum curators, the last shuttle and Soyuz crews could not salvage the hundreds of artifacts on the station.

The Mir space station was the world's first long-term, live-in space laboratory. It was launched on February 19, 1986, as a follow-on to the Soviets' Salyut series of space stations and ended up a high-profile international training ground for an unprecedented partnership. Surviving the disintegration of its mother country, Mir hosted seven U.S. astronauts as NASA retooled to support long-duration spaceflights, and more than 20,000 experiments, in fields ranging from medicine to astrophysics, were conducted.

Astronaut David Wolf, who helped restore Americans' confidence in the budding space partnership after a Mir-Progress resupply vehicle collision nearly toppled the alliance, would like to bring back the picture of Yuri Gagarin that is taped to a wall in the core module.

Shannon Lucid, who set a record for the longest spaceflight by a woman during her six-month stay on Mir, would like her books back. Lucid passed her spare time in space reading Charles Dickens and other books her daughters sent via resupply ships. "When Dickens wrote these books more than 100 years ago, would he ever have imagined in his wildest dreams that someday they would be aboard a space station?" Lucid wonders.

Her successor on Mir, John Blaha, stocked the station with videotaped Dallas Cowboy football games. Mir's



extensive video library also includes *Apollo 13*, subtitled in Russian, as well as *Star Wars* and *Alien*. In addition, Mir has a stereo, a ham radio, and dozens of books to help crews pass the time.

After a day in space, the commander and flight engineer would retire to their small cabins, about the size of telephone booths with sleeping bags hanging on the wall. Max Ary, director of the Kansas Cosmosphere and Space Center, would like to get his hands on some Mir hardware for his museum. "The stories those sleep stations could tell," he says. "The extraordinary boredom, the depression these men would feel after months and months in space, away from their children and their families."

Ary would gladly settle for the ivory-keyed command post where the crew tensely monitored the arrival of unmanned resupply ships. Cosmonauts would occasionally sacrifice the automated flight system to pack aboard other gear, and commanders would have to manually maneuver and park the seven-ton vessels using an old black-and-white

TV monitor to gauge distance. There were several close calls and one nearly devastating crash.

Mir, vacant since June, was scheduled to receive its final resupply vehicle at the end of January. Like the Progress vehicle already at the outpost, the last supply craft will contain only fuel, which will be used to steer Mir into the atmosphere for cremation. Its plunge will begin with a series of engine burns from the station's core module and conclude with a firing of the main engines of the two Progress ships. Deorbit maneuvers will take place when the station is 125 miles above the Atlantic Ocean and off the west coast of Africa. Several large chunks are expected to survive reentry and fall into the Pacific Ocean east of Australia, where what is left of the good ship Mir will be buried at sea.

—Irene Brown

States' Wrights

First came the license plates. Ohio's stated "Birthplace of Aviation," while North Carolina's countered with "First

in Flight.” Then, during the 2000 Democratic Convention roll call, North Carolina governor Jim Hunt declared his state was where the Ohio-born Wrights took their airplane on its first flight, which minutes later prompted Ohio delegates to chant “First in Flight!” when the chair called their state’s name. Now the battle has moved to U.S. currency: Both states want to use the Wrights and their Flyers on the reverse of their commemorative state quarters. North Carolina, which will have its name on about one billion quarters in March, says it will copy the famous photo depicting the 1903 Flyer lifting off from the sands of Kitty Hawk. Ohio’s, to be issued a year later, will depict the 1905 Flyer in one of three designs, to be chosen by the governor. (A fourth design—a cardinal, the state bird—won more votes in an Internet poll.)

“I’m flattered that North Carolina has chosen to put two Ohioans on their quarter,” says Stephen George, executive director of Ohio’s commemorative quarter committee. George remains gracious about the dispute. “All kidding aside, it’s a fact of history that the Wright brothers took their first flight at Kitty Hawk. If I were in [North Carolina’s] position I would take that for what it is: certainly one of the great accomplishments of humankind.” North Carolina has also taken the high road. “We get twice as much opportunity to build awareness of Orville and Wilbur,” says Carolyn McCormick of the Dare County Tourism Bureau, located near Kitty Hawk. “It’s a two-state effort now.”



RICHARD VANDER MEULEN

The Cox Communications Air & Motor Spectacular kick-starts the airshow season in Mesa, Arizona, on March 17 and 18 with a heavy metal theme. Monster trucks and jet-powered dragsters mix it up with the Blue Angels, the Smirnoff MiG-17s, a Yak 54, an AH-64D Apache Longbow, and Air Combat Command fighter demos. The 69th Battalion, which flies Vietnam-war era aircraft, simulates strafing runs, bomb drops, and crashes, and a C-130 slurry bomber drops 3,000 gallons of water. A thousand-foot Wall of Fire that burns 500 gallons of jet fuel in two seconds makes for a big finish. Standing room only: Cox predicts a crowd of 100,000.

COLLECTIONS

Airborne & Special Operations Museum

100 Bragg Boulevard
Fayetteville, North Carolina 28302
Phone (910) 483-3003
10 a.m.–5 p.m. Tues. through Sat., noon to 5 p.m. Sun. Closed Christmas and New Year’s Day.
Website: www.asomf.org

The U.S. Army Golden Knights dropped in on the opening of the Airborne & Special Operations Museum in Fayetteville, North Carolina, last August, along with 3,000 visitors who arrived via more conventional modes, while the U.S. Army 82nd Airborne Band played on and an Air Force C-130 and C-17 dipped their wings in salute overhead. The new museum, part of the U.S. Army Museum system, recounts the history of Army airborne and special operations units from 1940 to today. In the lobby, mannequins hang from a modern MC-4 High Altitude Low Opening square parachute and a World War II T-5 round parachute. Displays inside the 59,000-square-foot facility include a C-47 Skytrain flying low over a French village, a CG-4A glider disgorging a jeep, a special ops AH-6 “Little Bird” hovering overhead, a UH-1 Huey offloading troops in Vietnam, and an M551 Sheridan tank squatting menacingly in a corner. A large-screen theater portrays modern airborne and special ops action, and a Vista-Dome simulator mimics the sensations of parachuting and flying.



PATRICK TREMBLAY/ASOM



SFC KEN KASSENS/U.S. ARMY PARACHUTE TEAM

McCormick has not always been so sanguine. “Doesn’t Ohio have other stuff it’s happy about?” the *Cincinnati Enquirer* quoted her as saying when an Ohio state representative proposed adding the Flyer to the state’s seal. “When people think of Orville and Wilbur Wright, they don’t think of Ohio, they think of Kitty Hawk.”

Apparently that’s all behind her now. “My only comment is that in our minds the celebration has already begun,” she says, noting that one century ago the Wrights had already made their first trip to North Carolina’s Outer Banks.

George says the Flyer in the Ohio quarter is very different from the one on the North Carolina quarter. “The Flyer on the Ohio quarter, the 1905 Flyer, was the first aircraft that behaved the way an aircraft would—with sustained, maneuverable flight,” he says. [The Wrights] said this was their first true airplane.” It’s housed at Carillon Park—in Dayton, Ohio.

—Phil Scott

Satellites for Everyman

Arthur Blessitt is taking his religious sojourn to a higher plane. Last year, the Florida man walked into the *Guinness Book of World Records* after shouldering a huge redwood cross on a 30-year pilgrimage through 282 countries. In November, a small replica of Blessitt’s burden will be one of nearly two dozen payloads launched into Earth orbit from Russia aboard a decommissioned SS-18 intercontinental ballistic missile.

A cross whittled from a four-inch chunk of Blessitt’s will ride to space in a 2.2-pound box called a CubeSat. One Stop Satellite Solutions of Ogden, Utah, began selling the tiny spacecraft packages last November, promising to “make satellites affordable to the masses.” After launching several small satellites atop a converted U.S. Minuteman missile (the Minotaur) in January 2000, One Stop Satellite Solutions recently partnered with Thiokol Corp. and ISC Kosmotras to use

Russia's Dnepr—the new name for the demilitarized SS-18 (see “Rehab for Rockets,” Oct./Nov. 1999). “In the [START] treaty, they have to destroy over 150 of these launch vehicles,” says OSSS president Dale Richards. “We’re trying to get some useful commercial life out of them.” Only 21 academic, commercial, and private customers were signed up for the inaugural flight, but Richards says as many as 500 can be launched in a single mission using OSSS payload adapters. The company touts CubeSat’s “seemingly endless” capabilities, such as microgravity and biomedical research and space-rating small electronic parts. Personal applications include sending your loved one’s ashes to orbit and flying your name in space.

Blessitt is a perfect—albeit unusual—example of the customer OSSS wants to attract. A picture of a CubeSat with the caption “Swords to Plowshares” caught his eye as he was leafing through a magazine. “I’ve always wanted to carry the cross into space, but they don’t have those trips going yet,” says Blessitt. “Here is this technology, and it’s affordable enough.”

“CubeSats provide access to space for a mission at approximately \$45,000, which is millions of dollars lower than anyone else,” says Richards. Blessitt was able to scrape together a 10 percent down payment. Supported entirely by

donations to his ministry, he’s trusting God to deliver the rest by the time the Dnepr blasts off from Kazakhstan. Pound for pound, a CubeSat launch costs about twice the going rate of a conventional launcher. “But small satellites have not had many alternatives,” Richards says. “Nobody will launch one two-pound satellite, and that’s part of the problem. Universities’ small satellites have sat on the shelves for years.” Bob Twiggs, director of Stanford University’s Space Systems Development Laboratory, invented the CubeSat as a way to help doctoral students take a satellite project from concept through launch in less than a year. “I needed to find a quick way to build a satellite and a way to launch them at a reasonable price,” he says.

When Blessitt returns from a trek across Cocos Island, the Coral Sea Islands, and Tasmania in March, he will carve a chunk out of his cross, soak it in a preservative, and put it in the cube OSSS is providing. Most CubeSats are aluminum, but Blessitt’s box will be made of transparent Plexiglas. “My desire is to take it to the White House and show it to President Bush before we put it on the satellite,” says Blessitt. Most CubeSats will orbit at low altitude and be deorbited in a year or two to minimize orbiting junk, but Blessitt’s will go to perhaps 350 miles and stay up 150 years.

—Beth Dickey

UPDATE

Taking Liberty

It’s only hardware, but it’s a cut above your Home Depot stock. The Kansas Cosmosphere and Space Center is offering bits and pieces of *Liberty Bell 7*, the Gus Grissom Mercury capsule that sank in 1961, was recovered in 1999 (“Deep-Sea Fishing,” Above & Beyond, June/July 2000), and was restored to exhibit status at the Cosmosphere. Nuts, bolts, washers, pressure fittings, and segments of a landing bag assembly that were too corroded or compromised to reinstall are encased in wedges of acrylic, each with an image of the capsule and a certificate of authenticity. Prices start at \$150. Order by phone at (316) 662-2305 or (800) 397-0330, or on line at www.cosmo.org.

Saving Tranquillity Base

New Mexico State University student Ralph Gibson fears the future. “They come and before you know it they do a lot of irreparable damage,” he says. “With these robots they have planned, you can quickly ruin everything.”

Gibson’s fear is not of the bipedal robots of Terminator fame but of the wheeled remote-controlled variety. The kind of metallic claw-wielding machines that may one day be traversing the moon’s surface, from the lunar highlands to the Ocean of Storms, in the name of science, entertainment, and profits.

“Can you imagine what a remote-controlled rover can do to the Apollo 11 landing site?” asks Gibson. “Even if you succeed in not bumping into any of the artifacts, you still could easily run over the footprints that were left by Armstrong and Aldrin. And as an anthropologist, I feel those footprints up there are just as significant to human history as those of Cro-Magnon man down here.”

Gibson, grad student John Versluis, and their cultural resource management professor, Beth O’Leary, in whose class the whole subject came up, decided to protect the artifacts of Apollo 11 and the footprints of Neil Armstrong and Buzz Aldrin by making Tranquillity Base America’s most remote national park.

But the U.S. Park Service claims it has no jurisdiction for a plot of land 240,000 miles away from the nearest ranger station. Furthermore, the United Nations Space Treaty of 1967 declared the moon international territory.

The team, now backed by a \$23,000 grant from NASA and the New Mexico

BEST IN SHOW



CAROLINE SHEEN

The Rolls-Royce Aviation Heritage Trophy, which in 1999 was awarded to a Corsair, was last year given to...a Corsair. Awarded at the Reno Air Races last September, the second annual trophy was presented to Ray and Sherri Dieckman of Corona del Mar, California, for their FG-1D, deemed the best example of a restored vintage aircraft. The Corsair bested a field of 24, which included B-25s, a Grumman F7F Tigercat, a Spartan Executive, and a Spitfire Mk.XVI. To qualify for the invitational, which is sponsored by Rolls-Royce, the National Air and Space Museum, the National Aviation Hall of Fame, and the Reno Air Racing Association, an aircraft must have been flying 45 years prior to the competition, must be airworthy, and may not compete in air races.



Aurora borealis flows in great waves across Canada in this satellite image, created late last November after flares erupted on the solar surface. Charged particles from these flares interact with Earth's magnetic field, producing a high-altitude light show known as the Northern Lights. This image was captured by a U.S. Air Force Defense Meteorological Support Program satellite orbiting the poles at an altitude of 450 miles. DMSP satellites carry scanning radiometer sensors that can view Earth in visible, near-infrared, and infrared spectra day and night. Low-light sensors on the satellites capture visible images of erupting volcanoes, oil and gas fields, lightning, meteor trails, forest fires, and, of course, activity of interest to the military.

Space Grant Consortium, is working on a line of logic that may make even the United Nations take notice. "We are working to get Tranquillity Base declared a World Heritage Site by the U.N.," says

UPDATE



The Emperor's New Nose

Kudos to Antonov for upgrading the An-2 with a turboprop 1,375-horsepower Omsk Glushenkov TVD-20 engine. The upgrade resulted in an increase in payload capacity, range, and operational altitude. Practical as it is, this pairing of old and new is such an affront to aesthetics that we must move the new An-3 to the head of the class of atrocious aircraft featured in "Plug-Ugly" (June/July 1997).

Gibson. "If that happens, then the nations of the U.N. agree that this is a special location that needs to be preserved and rules are set in place to protect it."

While the U.N. has World Heritage Sites all around the globe, this is the first time a nominee is off-globe, which presents certain challenges for the New Mexico State team. For one thing, a complete inventory of all the items left on the moon must be made and their locations documented. "Neil Armstrong took the extension handle of a tool and threw it," says Gibson. "We need to know where that handle is." Gibson and Versluis researched archives at the National Air and Space Museum and NASA and have written to Armstrong and Aldrin to find out about Armstrong's handle, as well as the cameras, boots, bags, scoops, flags, and general litter that was left on the lunar surface.

It's a lot of work for a park that its promoters will likely never visit. "Who knows when we will venture back to the moon?" Gibson wonders. "But whenever people finally get to visit there, I think they will appreciate someone took the time to make sure it was just the way the Apollo 11 crew left it."

—D.C. Agle

Join our new
AIR & SPACE

ONLINE Reader Panel

and be entered to win a
digital camera!*

As part of the Reader Panel, you can tell *Air & Space* about

- what you read
- your interests
- your likes and dislikes
- your opinion of *Air & Space Magazine*

Several times during the year, we may ask you to participate in a survey. Answers will remain completely confidential.

How to join the Reader Panel:

- 1 Go to www.airspacemag.com
- 2 Click on the "Reader Panel" area.
- 3 Fill out the online Reader Panel survey, submit your answers, and you'll be entered to win a digital camera!

* Complete sweepstakes rules and digital camera details are located on the *Air & Space Magazine* web site.

JOIN NOW!

Go to
www.airspacemag.com

Italian Lightning

One of the most effective fighters in the early part of World War II was the Italian Macchi C.202. Outside Italy, however, it failed to achieve as much fame as contemporary fighters of other nations. Known by the pilots who flew it as the *Folgore*, meaning "lightning," it was the finest fighter of the *Regia Aeronautica Italiana*—the Royal Italian Air Force—and raised the level of Italian fighter development to international standards.

The Macchi C.202 in the National Air and Space Museum's World War II aviation gallery is one of only two remaining in the world. The early history of this airplane is obscure, but it was one of many enemy aircraft brought to the United States after World War II for evaluation at the Army's Air Technical Service Command at Wright and Freeman fields in Ohio and Indiana, respectively. In 1975 Museum technicians restored the fighter to exhibit condition.

Flown initially in August 1940, Macchi C.202s joined their first unit, the 1 Stormo C.T., in the summer of 1941. By November, that unit was transferred to Libya to participate in the last stages of the British campaign that led to the raising of the blockade around Tobruk and the retreat of the German and Italian troops in Cyrenaica in late December.

Its late arrival in battle was a contributing factor to the success of the British offensive. This new Macchi made its mark as an outstanding fighter, however. In capable hands, it was a challenge to its North African adversaries, being superior to both the American Curtiss P-40 and the British Hawker Hurricane by a substantial margin. It could outmaneuver any of its opponents and outperform all but the late-model Spitfires and Mustangs. Pilots who flew the *Folgore* lauded its finger-light handling and its superb agility.

The success of the *Folgore* was due largely to the use of the in-line, liquid-cooled engine. Although Italy had gained the world speed record in 1934 with its in-line-engine-powered Macchi C.72, the

Italian aircraft industry ignored this speed potential and stayed with the more easily maintainable, yet bulky, radial engine. Its fighter force suffered from this policy.

It was not until the opening months of 1940 that the Macchi Company, as a private venture, imported an example of the Daimler-Benz D.B.601 in-line engine from Germany and designed a slender fuselage around it. Utilizing the wings and tail design of the Macchi C.200, the new airplane became the C.202. Results with this new design were impressive, and production began at once.

An interesting but hardly noticeable fact is that the left wing of the *Folgore* is eight and three-eighths inches longer than the right wing. Only a few aircraft designs have used such asymmetry to counter the rotational torque of the

engine in order to assist pilot control.

The Macchi C.202 was produced in larger numbers than any other Italian monoplane fighter, and although it was well regarded by the skilled pilots who flew it, the lack of an effective propaganda effort deprived the *Folgore* from getting a widespread reputation. The airplane was used on a small scale by the Germans, and after 1943 it appeared in the small Italian Co-Belligerent Air Force, which operated continuously from the Italian Armistice until VE Day. The C.202's service ended where it all began, in the North African skies, while serving with the Egyptian air force.

—Robert C. Mikesh

Adapted from Aircraft of the National Air and Space Museum, edited by F. Robert van der Linden, Smithsonian Institution Press, 1998.





VISITING THE MUSEUM

Hours The National Air and Space Museum is open from 9:30 a.m. to 5:30 p.m. The Museum is open every day except December 25. General admission is free.

Location The National Air and Space Museum is located on the National Mall at 7th Street and Independence Avenue SW, Washington, D.C., just west of the U.S. Capitol. The closest Metro stations are L'Enfant Plaza and Smithsonian. The Museum is currently undergoing renovation; some galleries will be closed temporarily. For detailed information on gallery closings, visit the NASM Web site at www.nasm.edu/nasm/NASMexh.html.

Tours Free docent-led tours are given daily and depart from the Tour Desk, South Lobby, Gallery 108. Audio tours describing NASM artifacts are available in English, French, Spanish, German, and Japanese. The audio tour kiosk is located near the Information Desk in the South Lobby. Headset fees range from \$4.50 to \$5.

Samuel P. Langley Theater Experience the thrill of films produced in IMAX and projected onto a screen seven stories wide and five stories high. Feature films include *Cosmic Voyage*, *To Fly!*, and *Mission to Mir*. For more information, call (202) 357-1686 or (202) 357-2700.

Garber Preservation, Restoration and Storage Facility Reserved Tours Get a behind-the-scenes look at the restoration workshop in Suitland, Maryland, where skilled craftsmen restore aircraft and flight-related artifacts. Free tours last approximately three hours; reservations must be made at least two weeks in advance. For information, call (202) 357-1400.



During the summer of 1942, this Macchi Folgore fighter (above) was operating out of Libya as part of 4 Stormo, 10 Gruppo, 90 Squadriglia. Formed in 1940, the 4 Stormo was credited with 500 victories. The fighter's camouflage pattern of light sand with green splotches is duplicated on the National Air and Space Museum's Folgore (top).

OBITUARY

National Air and Space Museum employee Francis P. Tunstall Jr. passed away on December 11, 2000. Tunstall, 53, restored vintage aircraft as a museum specialist at the Garber facility. A decorated pilot with nearly 3,500 hours, Tunstall retired from the U.S. Air Force in 1991 as a lieutenant colonel.

Jump Ship

In 1942 the U.S. Army Air Forces held a competition for development of an autogiro that could take off and land vertically with little or no roll, unlike the typical autogiros of the day, which required a short takeoff roll. The AAF wanted an aircraft that could be operated in close confines. Prototypes of the Kellett XO-60 and the Pitcairn XO-61 "jump giros" were evaluated, and Kellett won a contract for six YO-60s. (The XO-61 had run into cooling and power problems due to its pusher propeller configuration.)

The following year, my outfit, the 445th Test Squadron of the 50th Fighter Group, stationed at the Air Forces School of Applied Tactics at Orlando, Florida, was tasked with determining how these aircraft could best be used in combat operations. Lieutenant Bob Miller and I, both primarily fighter pilots with no prior experience with such strange aircraft, were ordered to pick up two at the factory in Lansdowne, Pennsylvania, and fly them to Orlando.

In the course of some 20 hours of training under Kellett chief test pilot Dave Driskill, we learned that taking off vertically in the YO-60 was a complicated process, and dangerous if mishandled. Driskill had been in a near-fatal accident in the prototype, and he delighted in showing the resulting scars to us novice giro pilots to drive home the importance of proper technique.

An autogiro uses a standard propeller to pull it through the air, and the airflow over the rotor blades turns its freewheeling lifting rotor. A jump giro has an auxiliary drive shaft from the engine to the rotor, which allows the rotor to build up speed in flat pitch while on the ground, storing kinetic energy like a flywheel. The stored energy allows the aircraft to rise vertically when the pilot abruptly increases rotor blade pitch to lift off. A clutch then disengages the drive shaft to prevent rotor torque from spinning the jump giro like a top.

The YO-60 had a conventional throttle for the 300-horsepower Jacobs engine, a

constant-speed propeller on the nose, and traditional stick and rudder controls. However, because of excessive feedback from its mechanical connection to the rotor that caused the stick to thrash about at low rpm, the control stick was secured in a lock on the instrument panel unless rotor speed was above 200 rpm. Only then could it be disengaged. During takeoff, the pilot held it firmly forward and right, to counter rotor feedback and engine torque.

Power was taken off a drive shaft from the rear of the engine to the rotor head and was engaged by a T-handle clutch on the left side of the instrument panel. There was also a rotor pitch-angle lever that the pilot pulled back and locked for flat rotor pitch during rotor rev-up. On top of this lever was a red quick-release button that caused a spring-loaded nine degrees of pitch to be suddenly applied to the rotor blades to facilitate a jump takeoff. All these exotic controls were very confusing to the student pilot, and if not used in proper sequence, the results could be disastrous.

Lightly loaded and in cool weather, the YO-60 could make a spectacular vertical takeoff. It could jump five to 15 feet straight up before accelerating forward in a climbout. In hot weather, with a full load of fuel and a passenger, it would merely lurch into the air, where its straining engine and propeller could eventually make it climb rather handily.

Landing gave us fits. It required one to glide down final approach at only 40 mph, flare at an exaggerated angle 10 feet off the ground, and in this absurd nose-high attitude, allow the aircraft to settle on its tail wheel, then pitch forward onto the nose gear.

After 20 hours of dual and solo flight, we two newly certified autogiro pilots flew the YO-60s to Orlando on a circuitous route: The jump giros had fuel for only two hours, cruised rather slowly, and, since the program was classified, could be refueled only at military bases.

From our training, we were accustomed to landing on the ramp in front of operations, rather than on the long runway with the usual traffic, so we asked the air traffic controllers at various airports if we could land on the ramp. Occasionally, if a ramp had open space, our requests would be granted. Most times, though, we were sternly told to land on runway so-and-so. If we repeated our request, we were asked just what sort of aircraft we were flying that could land on a crowded ramp.

On one occasion, with the tower's permission, we landed right in front of base operations at Richmond Army Air Base in Virginia. The ops officer, who had not heard our conversation with the tower, spied us through the window and came storming out, ready to throw the book at us. But as he took in the sight of the strange wingless aircraft that had landed almost vertically on his crowded ramp, his stride slowed. By the time we shut down and got out of the aircraft, he was cordial, full of questions and begging for a ride.

Less than two weeks after we got the YO-60s to Orlando, Miller was killed while flying a Bell P-63 Kingcobra. In an evasive maneuver during a mock dogfight with a P-51, he flew into a thunderhead and spun out the bottom. At the time, I was flying one of the YO-60s, and, hearing a report of the crash, spotted the wreckage. I checked in with the tower, then flew slowly ahead of the ambulance and crash wagon, leading them down back roads and across fields to the scene. It was a terrible loss.

Because of the YO-60's classified and unconventional nature, we had been ordered not to check anyone else out on the aircraft. Now the tactical test program was mine alone.

I flew at Camp Rucker in Alabama for the Infantry Board, at Camp Bragg in North Carolina for the Artillery Board, then finally with a division training in Florida for overseas duty. There I faced some unusual hazards. I delighted in landing in tight spots near "enemy" lines,

On a cool day, with a bit of wind and a light load, the Kellett jump giro could leap straight up some 15 feet, gain forward speed, and climb out. But in hot weather and still air, with a full load of fuel and a passenger, it merely lurched upward, relying on its straining engine and propeller to pull it out.



COURTESY E. STUART GREGG

but often these tree-lined sites were much too tight to attempt a takeoff. I did a lot of taxiing along roads in the woods and between trees, dodging branches that could hit the delicate rotors, while searching for sufficient open space for a safe takeoff.

We learned a lot from these operations in the field. For one thing, the YO-60 was very sensitive to rotor trim. Metal trim tabs near the ends of each of the three rotor blades sometimes had to be adjusted on the ground and by hand. Bang a rotor tip on a branch, or subject the fabric-covered blades to prolonged moisture, and when you revved the rotor, the YO-60 would oscillate and dance alarmingly on its spidery landing gear. Several times I had to rectify bent trim tabs and rotor imbalance with a pair of pliers—real shade-tree maintenance.

Ultimately, these field tests showed that in some respects the YO-60 could outperform the L-3 Aeronca, L-4 Piper, and L-5 Stinson liaison aircraft, but it was more expensive and complicated to fly and to maintain in the field.

The sight of this bizarre aircraft flying at low altitudes around northeast Florida occasionally prompted unusual requests. One day, Orlando sent down word to fly the YO-60 to the football stadium in Jacksonville, and report back if I thought I could land on and take off from the football field inside the stadium. After a casual flyby, I reported that it looked doable, so I was told to fly out of the

stadium as a stunt for a war bond rally.

At twilight on the evening of the rally, with my crew chief in the back seat, I landed in the middle of the field. No problem. In the waning daylight, the prospect of a takeoff from this limited space seemed easy enough. But as darkness descended and the rally droned on, the tiers of stadium seats seemed to increase in height alarmingly.

As things finally began to wrap up, I was asked to tell the crowd about this unusual aircraft. Dry-mouthed, I mumbled a few sentences into the microphone, then climbed into the YO-60 and went through rev-up. As insurance, and out of desperation, I exceeded the rotor rpm redline and popped the quick-release pitch button, only to have the YO-60 stagger a few feet upward in the hot, still air, then fall back almost to the ground. The engine was snarling and the propeller did its best to pull us up and out of that big hole. I counted the entire alphabet of seat rows as we clawed our way upward. After I barely cleared the row of flagpoles and the stadium lights, everything immediately went black. The only instrument-flying aids the YO-60 had were rudimentary gauges, and I had never flown it at night. I resolved never to try a fool thing like that again.

Late in 1943, before the YO-60 test program was complete, I was ordered to

the Sikorsky factory in Bridgeport, Connecticut, to evaluate the YR-4B helicopter. After just a few hours of flying, it was clear that the primitive but functional machine could perform vertical takeoffs and landings with far greater ease and dexterity than a jump giro—an observation I included in the final test report of the YO-60, virtually killing further military procurement of autogiros.

When I was sent overseas for combat duty in 1944, the YO-60s were still sitting on the ramp at Orlando, with no one there authorized to fly them. I later heard that a few jump giros were sent to Texas to join the conventional autogiros the border patrol used, and that every YO-60 crashed. Having been fortunate enough to have flown 150 hours without an accident in this imperfect, somewhat dangerous, but strangely enjoyable aircraft, I wasn't surprised.

Nearly 60 years after the fact, I can now confess that in spite of regulations and common sense, I often used a YO-60 to fly home for lunch, landing in my front yard. I also flew it to the local golf course, where I landed on the ninth fairway, parked behind the caddy shack, and put in a quick nine holes of therapeutic golf.

—E. Stuart Gregg

Body by Erco

Nearly 50 years after the Engineering and Research Corporation (Erco) ceased production of the Erco, the “airplane anyone can fly,” the Erco Owners Club still holds an annual national fly-in. The most recent one was part homecoming, part farewell to the Erco’s birthplace.

Last July, 220 people and 62 aircraft gathered at College Park Airport in Maryland, outside Washington, D.C., and a mile from the former Erco factory. Part of the spacious old building now serves as a distribution center for aeronautical and nautical charts. But it was recently sold to a developer, which probably means there’s a wrecking ball in its future. The fly-in featured tours of the factory, led by Erco alumni who returned for a last look.

It was here that Henry Berliner founded Erco in 1931 as a haven for engineering innovation, and despite the Depression, the company had plenty of capital, thanks to royalties earned by Berliner’s father, Emile, inventor of the disc phonograph and a microphone for early telephones. Berliner outfitted his plant with features luxurious for the day, such as an early form of air conditioning. Elegant touches are still visible, like the richly grained wood in the lobby and conference room, and the walls of glass brick, now painted.

The machinery is long gone from the echoing halls. Returning Erco employees pointed to telltale outlines on the floor, showing where the 2,000-ton hydraulic press stood, the boring mills, the grinders. The 35,000-square-foot final assembly shop, which once produced up to 34 Erco’s a day, is now empty save for a basketball net, used by workers from the parts of the building still occupied.

In addition to Erco’s, the company built and sold machine tools for aircraft manufacturing and other industrial uses. Starting in World War II, Erco produced gun turrets for bombers, and the tour guides recalled the sound of machine gun fire in the surrounding woods as the units were tested. Other products made during and after the war included radio antennas, external fuel tanks, bomb racks, rocket



COLLEGE PARK AVIATION MUSEUM

launchers, and afterburners. Erco devised dispensers for chaff, aluminum strips dropped from bombers to thwart radar. Even bodies for bread trucks and school buses came off the Erco assembly line.

Despite having little experience in electrical engineering, Erco landed a postwar contract to build some of the first aircraft-specific simulators, such as those for the F9F Panther and the F-86D Sabre. “Compared to today, they were extremely primitive,” says Howard Benson, an engineer on the project. “I invented the lightning simulator, which was flashing lights around the translucent canopy. Rough air simulation was a cam-driven shaft under the ejection seat, which would jump the seat up and down. That was the extent of the visual and motion.”

The Erco was the brainchild of Fred Weick, Erco’s chief engineer. The number of private pilots was expected to grow, and the Erco was designed in 1937 to be “unusually simple and easy to fly,” he said. Innovations included tricycle landing gear with the nose wheel connected to the control wheel, so it could be steered like a car, and a conjoined aileron-rudder system also controlled through the wheel, which eliminated the need for rudder pedals. Because a pilot could not cross-control the airplane, the Erco was impossible to spin. But pilots balked at single-axis control, so later models offered the option of rudder pedals.

Erco alumni and Erco owners speak reverently of Weick. “He was a

genius, a national treasure,” says Joe McCawley, board chairman of the owners club. Weick died in 1993, but his children, Donald, Betsey, and Dick, attended the 2000 fly-in. They described the W-1, experimental forerunner of the Erco, taking shape in their garage. Donald’s tricycle was sometimes used to demonstrate the landing gear configuration. They recalled the lanky frame of their father, stretched out on the floor after an exhausting day at the plant. “No couch was big enough,” Betsey explained. “He’d take up the whole floor. We’d walk very quietly around him.”

Erco produced almost 5,100 Erco’s, and companies such as Forney, Alon, and Mooney later built 500 of their own versions. At the fly-in, a “Coupe Showcase” displayed examples of all but one of the models. Weick and his team had been working on the prototype of a four-seat Erco, but the project was cancelled when the market for private aircraft plummeted in the late 1940s. Erco club members Marvin and Ruth Dunlap learned the whereabouts of the unfinished airframe and bought it in 1990.

They’ve been working on it ever since at their home in Michigan. Starting with just a fuselage section, they’ve had to add wings, a tail, an engine, and much more. They aim to fly their one-of-a-kind Erco to this year’s fly-in in Terrell, Texas. Says Ruth Dunlap: “It’s going to be a new, old, 1947 four-place Erco.”

—Lester A. Reingold

"What risks he took! What innovations he made!"



"Every time I'm in Washington I make sure I visit the Hughes Racer and then attempt to discover something new off in some corner of the Museum. I am never disappointed."

—AEROSPACE ENGINEER ED SACHTLEBEN stands before the Hughes H-1 Racer in the Museum's Golden Age of Flight Gallery. Designed by Howard Hughes and Jack Peltzer, Hughes smashed the world speed record and transcontinental speed record with the H-1 in 1931.

For years, brilliant Howard Hughes' aircraft company was on the cutting edge of aviation. With a new engineering degree, Ed Sachtleben knew Hughes Aircraft was where he wanted to be. That began a 34-year career of designing satellite control systems — and a lifetime of admiration for Mr. Hughes and his engineers.

Ed Sachtleben knows the National Air and Space Museum shares his respect for aviation and space

history. He's proud to have included the Museum in his estate, and is now a member of the *Smithsonian Legacy Society*.

Find out how you can include the National Air and Space Museum in your estate plans. Fill out and return the reply form below, or call 202-357-2493. You may also e-mail gayle.union@nasm.si.edu. Help honor the legacy of innovation!

Innovation

Please Give to the Smithsonian's National Air and Space Museum

☐ **YES!** Please send me information on how to include the National Air and Space Museum in my will or living trust.

☐ I have already included the National Air and Space Museum in my estate plans.



Smithsonian
National Air and Space Museum

Name _____

Address _____

City _____

State _____

Zip _____

Daytime Phone Number _____

E-mail _____

All replies are confidential. Mail to: Gayle S. Union, National Air and Space Museum, Suite 3712, Independence Avenue at Sixth Street, SW, Washington, DC 20560-0321, **Phone:** 202-357-2493, **E-mail:** gayle.union@nasm.si.edu



SWITZ

According to aviation myth, Swiss fighter pilots wait in their cockpits around the clock in secret mountain caverns, ready to yell "Chocks out!" (or the French, German, or Italian equivalent) when word comes of an intruder. Then they burst from their caves like bats on afterburners, airborne and wheels up a few meters from the granite wall. It is a wonderful image, but reality is better.

Reality, on this hot, hazy spring afternoon, is a cavern at the Swiss air force base at Buochs, south of Lucerne. You reach it by taking a left between the Evinrude and Volvo-Fiat dealers, then another left along the base of the mountain that flanks the aerodrome. And there, almost hidden in an embrace of trees, a net made of artificial leaves floats above a recessed concrete and metal face cut into the mountain. Dappled light blurs the rust and green camouflage. A sharply contrasting red sign attached to the steel wall yells STOP! at any unauthorized wanderers, and, by an open door in the metal face, a young sentry in battle fatigues reinforces the idea with a cradled Sturmgewehr 90 assault rifle.

The cavern belongs, more or less, to Jean Vienne, whose fatigues bear the collar patch of a warrant officer. He is a military instructor at Buochs, where a 150-hour training course on cavern operations is just coming to an end. Most of the people in the class—pilots, ground crew, armed sentinels—are militia, part of Switzerland's citizen-soldiery, doing their compulsory military service at a rate of a week or three a year.

Not Vienne. He is a professional soldier, one of the relative handful of lifers who are the reliable heart of the Swiss armed forces. He has spent 25 years in the army, which owns and operates the caverns in which the air force caches its fighters, and he specializes in aircraft electrical systems. Born in the Netherlands of Swiss parents, Vienne speaks the three main languages of Switzerland, plus Dutch and English, which makes him a good man to have with you in the field.

The narrow, guarded entrance opens into a hall about the size of a two-lane tunnel, of the kind that abound in Switzerland's road system, its arched ceiling illuminated with banks of lights. The difference is that this tunnel has a polished concrete floor, painted with curving tracks of red and green, labeled "Tiger" and "Mirage." The smooth curve of the ceiling is broken

A Swiss F/A-18C pilot cavorts in his own neighborhood before mixing in multi-national exercises.

here and there by thick hanging bulkheads with spaces cut out to allow the passage of airplanes.

Farther into the cavern, the tunnel snakes off to the right—a protective offset, should anyone toss a bomb through the cavern door—and then straightens to a second metal door painted with yellow and black chevrons that blocks the way like a great cork in a bottle. Beyond this seal lies the amazing vault where the aircraft wait.

Here the arched ceiling seems to reach to the vanishing point in a haze of light. What look to be a dozen gray Northrop F-5 Tigers bearing the Swiss cross stand on the gleaming floor, arranged in closely packed echelons, noses forward. The front four aircraft have pilots in the cockpits, preparing the Tigers for flight, and also ground crew crawling busily over them.

The cavern, Vienne notes, penetrates about a thousand feet into the mountain and is designed to withstand overpressures (from bomb blasts) of 15 bars—that is, 15 times the standard atmospheric pressure at sea level—which is about 220 pounds per square inch. Racks on the walls hold drop tanks and other external stores. Overhead, a crane that can lift, transport, and rotate airplanes in the narrow tube rides on a track along the centerline of the tunnel. Beyond the farthest airplane is another bulkhead, and, beyond

BY CARL POPEY

TO THE WORLD'S MOST FORMIDABLE NATURAL DEFENSES, THE SWISS HAVE ADDED F/A-18 HORNETS AND A NEW SLANT ON NEUTRALITY.

PHOTOGRAPHS BY KATSURIKO YOHUNAGA

Don't Mess With SWITZERLAND



When is reconnaissance more like sightseeing? In a Pilatus Turbo-Porter over Aarau. More commonly the Porter is on the lookout for avalanches, fires, or injured persons.

that, one presumes, are quarters, supplies, arsenals—the airplanes can be fully replenished with fuel, oxygen, and armaments in this enormous, hidden hive.

Now the chevroned metal door splits in the center, and the two halves glide into the cavern walls. What had seemed to be metal blast shields along the bases of the doors are covers for the groove in the floor, and, as the doors slide outward, the covers drop into place—plop, plop, plop—as precisely as the steps of an escapement in a fine watch.

Four tractors hitched to the manned Tigers' nose gear begin towing the airplanes toward the light, careful to follow the painted floor line marked "Tiger," as clearances are tight. Each airplane is trailed by its ground crew, through the narrow curve of the "S," out through the huge entry doors. A few hundred feet from the cavern, the four Tigers fire up and are sent on their way. Within three minutes, they are climbing out of the valley, two by two.

It is not the lightning-quick launch depicted in comic books, and the pilots will not spend very long in the air, at the ready; instead, they will fly their sortie and return to another nest here in Buochs or in one of the other military fields dotting the country. And then everyone but Vienne will go home. The cavern is a wartime base, in a nation that has not been at war for centuries, and yet has been armed the entire time, just in case.

Years ago, signs near Swiss military air fields warned passersby against photographing anything. Then, in 1991, the signs were changed, allowing photos of anything visible from public ground. And then the signs just disappeared. Now Swiss air bases are among the most open in the world,

and U.S. journalists are welcomed into secret caverns. The gradual thaw is the result of global changes, certainly, but also of events in Switzerland's history.

In the 1980s, the Swiss air force's frontline interceptors were Dassault's Mirage III and Northrop's F-5 Tiger. The Mirage is a 1960s design but formidably supersonic, and the F-5 offered simplicity, speed, and a radar cross-section so small that the fighter is still hard to hit. But in a world awash with supersonic BVR—beyond visual range—shooters, the Tigers and Mirages were inadequate. In 1986, the Swiss air force went shopping for something better and, in October of 1988, opted for the McDonnell Douglas (now Boeing) twin-engine F/A-18 Hornet. Parliament duly appropriated funds for a buy of 26 single-seat C models and eight two-seat D models. Whereupon little Switzerland became a Hornet's nest of controversy.

Groups the government characterizes as left-wing and environmental mounted an intensive anti-aircraft campaign, gathering signatures for a national referendum on whether the country should modernize the air force. In June of 1993, not quite five years after the decision to buy the Hornets, the matter was put to a popular vote (the question phrased, as referenda often are, so that a "no" vote actually said "yes" to the Hornets). The new aircraft carried 57 percent.

The first Hornet, a D model, arrived in Switzerland in December 1996, followed in early 1997 by a C model, and then by 32 kits for assembly at the sprawling government-owned Swiss Aircraft and Systems Company, once a federal factory, in Emmen, near Lucerne.

The delay proved to be no bad thing, for it allowed the Swiss to acquire the superior APG-73 radar and the more

powerful General Electric F404-GE-402 engine of the C and D models. Coincidentally, 1997 was the year the Swiss air force phased out its cold war tactical language, an argot called *Bambini*, fashioned from German, French, and Italian, in favor of a new *Bambini*, called English.

The Swiss flying service was established just before the 1914 assassinations of Austrian royalty in Sarajevo. Nine pilots reported for duty near Bern's Wankdorf stadium, some with their own airplanes and mechanics. But this fledgling air arm was a mere peripheral until the 1930s, when all the surrounding countries began strapping on winged weapons. The Swiss elevated their air force to branch status and began purchasing equipment: Messerschmitt 108s and 109s from Germany, along with three Junkers 52s and nearly 300 French Morane D-3800 and -3801 fighters, the last assembled at Emmen.

This invigorated force saw action early in June 1940, when it destroyed nine Me 110s violating Swiss air space. Three Swiss airmen were lost in the Luftwaffe vs. Luftwaffe skirmishes. After that, air combat was forbidden until October 1943, and no Swiss fighters have engaged an enemy since. Military fields moved into narrow alpine valleys—to Meiringen, Alpnach, Turtmann. The pastoral fields were cut by runways and dotted with low concrete and steel bunkers called *Unterstands*, covered with a layer of sod thick enough to root a stand of trees. By war's end, the Swiss border had reportedly suffered 6,501 violations, and 244 foreign aircraft had landed, crashed, or been shot down.

In the late 1940s, the Swiss air force moved boldly into the Jet Age, buying 182 British de Havilland Vampires, a Barney Baxterish, twin-tailboom design. The Vampires joined some remnant Messerschmitts, Fieseler Storchs, Ju 52s, Morane C-3603s, AT-6s, and Mustangs, these last bought at a bargain-basement price from the U.S. Air Force. Soon the original Vampires, which would serve until 1990, were augmented by 250 de Havilland Venoms, flown until 1984.

If there has been a golden age of Swiss fighter aviation, however, it would have begun in the 1960s, with the arrival of the first Hawker Hunters. Long after the Vampires and Venoms and the rest had been consigned to the Swiss museum of flight in Dübendorf, or mounted on pedestals outside air bases, or scrapped, the Hunters would remain Switzerland's all-purpose fighter—until the Mirages and Tigers took over.

Payerne is Switzerland's largest military field, spread across high, flat meadows southwest of Bern and, like most bases today, accessible to all. Civilians park along the drainage ditches near the runway to watch the comings and goings of Switzerland's newest and hottest interceptors, the Hornets, which live in drive-through hangars called boxes. Earth-covered *Unterstands* rise like druid mounds but are almost invisible against the surrounding farmland.

Because in Switzerland one always looks for the object hidden in plain view, I note that the auto route paralleling the main runway lacks the usual edelweiss hedge along its centerline. The traffic streams are separated by a metal fence whose removal transforms the road into another long,

unobstructed runway. Inside the base proper, which is guarded by a Vampire on a pedestal, a new glass and steel building, housing offices and the Hornet simulator, rises from a field of ancient wooden billets.

Perhaps the best known Hornet pilot in Switzerland is Major Stephane Rapaz, 39, one of two selected for training at the Naval Air Station in Jacksonville, Florida, and the pilot who showed off the Swiss Hornet at foreign airshows. But he is also an experienced Hunter and F-5 hand, with five years in the Patrouille Suisse, the national aerobatic demonstration team.

Talking over coffee in the base canteen, Rapaz moves seamlessly from his native French to German to the assured colloquial American you'd expect from a Swiss pilot who trained with the U.S. Navy and is carrier qualified. In four years he's logged about 800 hours in the F/A-18, very little of it spent in transit. "The good part of our way of operating," he says, "is we are close to training areas. Ninety percent is training." On the other hand, it means pilots get little experience in air-to-air refueling. "We have no tankers, no buddy-buddy Hornet to Hornet. We had training in the U.S., but we didn't stay current." In fact, as he spoke, the Swiss were about to start a brief exercise with the French air force, in which Swiss F/A-18s would practice drinking from French KC-135s and fly against Mirages from Dijon.

Emerging from its cavern at the Buochs air base, a Mirage III recce jet prepares to make the rounds.







F-5E Tigers of the Patrouille Suisse roar toward the Matterhorn.

"We have about 20 memos of understanding with every country around us for training," he explains. Switzerland offers a narrow practice area about 50 miles long, which is not much ground for fast jets and imposes a host of other constraints. Going supersonic below 30,000 feet is forbidden—a sonic boom lights up the air force switchboard with complaints of shattered windows and cows gone berserk—and pilots may only rarely drop below a thousand feet.

Moreover, the airspace over Switzerland is the aeronautical center of Europe and is dark with traffic. If you superimpose a day's flight tracks on a map of Switzerland, the country simply disappears. Controlling this mass of moving metal is a civilian system operating in parallel with a military one. "In the training area," explains Rapaz, "the military guy's coordinating with European Control Center. But when you're four against four and they bring a guy across your area at flight level 300..." He rolls his eyes. A new system called HELCO (from *Helvetica Control*) is supposed to help by merging military and civilian air traffic control.

The only way the Swiss Hornets can break into the open is to go overseas, as they do each June for Exercise Norka. Run out of Royal Air Force Waddington in Lincolnshire, England, Norka offers space-challenged military pilots a chance to hone and measure their skills over the British Aerospace Air Combat Maneuvering Instrumentation range in the North Sea.

In the old days, the Swiss would arrive in their plump Hunters, lean Tigers, and swift Miros to fly against the best Europe had to offer. Now they travel to Waddington in a swarm of C and D Hornets and their company of F-5s, including a pair wearing the brilliant red and white livery of the Patrouille Suisse, to act the enemy.

Despite their reputation for doing everything their own way, the Swiss bought Hornets that are pretty much standard Navy issue. The differences are a stronger titanium alloy in the fuselage main bulkheads, to keep the Hor-

nets in service 30 years, and the substitution of an Emmen-designed low-drag weapons pylon for the stock multi-purpose stump on the U.S. F/A-18, which, Rapaz says, "was close to a garage door" in terms of drag. In doing this, the Swiss Hornets effectively abandoned the "A" in F/A-18, with the air-ground role passing, for the moment, to the F-5. This is not to say they launch light. The Swiss Hornets can carry Sidewinders and as many as eight advanced medium-range air-to-air missiles.

Exercise Norka offers the Hornet drivers what the world cannot: war in the air, or at least a close approximation. On many days, four dozen airplanes are up, in various confrontational line-ups: four Tigers against two Hornets, or four Hornets against four Dutch F-16s, or pairs and quartets of Hornets against British Sea Harriers and Tornados.

Three operational Hornet squadrons of eight aircraft each stage from Payerne and Dübendorf, with the remaining Hornets kept in reserve. In an emergency, the aircraft would move to war bases—that is, the new, larger caverns now being blasted in mountainsides at Meiringen, Sion, and Payerne. These will be much like Vienne's Tiger cave at Buochs, except that the beefy newcomer won't be hoisted around by overhead cables, and permanent power units placed near the cavern entrance will speed engine starts.

Thus far, only one Hornet has been lost. In April 1999, a two-seater D model Hornet crashed, killing the two Swiss pilots aboard, and the incident reverberates through every conversation. In an air force that adds only six Hornet pilots per year, the loss was staggering.

The Swiss, while neutral for centuries, have never been what one would call violence-averse. Their medieval infantry was highly regarded, and it did much to enrich the

homeland with the spoils of other people's wars.

Even if the Swiss didn't take sides in the 20th century, living neutral in the heart of Europe has been like living in the calm eye of the strongest hurricane. The eastern hinge of World War I's Western Front reached almost to the Swiss border, and war threatened to spill into the Alps. A generation later, every conquest by Hitler caused the Swiss to shudder, believing they

must be next, and not without reason; after the fall of France, the Germans thought it was time to relax and enjoy the new Nazi Europe. Switzerland bravely declined, and made its decision stick.

It could get away with such behavior because it had revived its ferocious infantry in the form of a citizen army, in which every able-bodied male must serve a minimum amount of active duty (about 300 days), and every militiaman keeps his rifle and a sealed box of ammo at home. Until recently, the armed forces numbered some 600,000, in a country of just over six million.

This force was then deployed in an area about half the size of South Carolina along a natural Maginot Line traversed only through high mountain passes, narrow valleys, and tunnels. Labyrinthine strongholds were scooped out of the country's rocky innards for fortresses in the Sargans area, near the Austrian border; another at St. Goddard, the portal from the south; and a third at St. Maurice, near France. Around this iron triangle, hidden traps were set.

Should an intruder batter past the fortresses, he would find his prize exploding everywhere around him, as the Swiss would sever their railways, tunnels, bridges, and roads at several thousand permanent demolition points. The only way to cross Switzerland would be the hard way. Nobody wanted to wrestle the little porcupine.

No sooner had Nazi Germany gone away than a new threat materialized, which, while never expressed too baldly—no one cried "The Russians might be coming!"—definitely lay to the north and east. Hardly anyone believed that an attack on Western Europe would bypass Switzerland.

A more immediate problem was that the radioactive detritus of a nuclear exchange wouldn't observe national frontiers. The Swiss built dwellings with massive foundations in which residents could take shelter. In rural villages, communal shelters were constructed, providing food, water, filtered air, beds, and baths. Should the cold war turn hot, 95 percent of the population would have a place to go. So would the jets, the first caverns for which were begun in 1949.

Until the late 1980s, Switzerland was the granite fortress of legend. Its mountain chains were likened to battleships run aground, and the valleys, with their runways to nowhere and secret redoubts, evoked stranded aircraft carriers. And, hidden in those caverns, pilots waited like medieval knights in gray armor, in their Vampires and Venoms, their Hunters and Tigers and Miros, for the war that never came.

For the last half of the 20th century, the Swiss military comprised, on the one hand, a fully democratic citizen's militia, in which truckdrivers ordered bankers around, and, on the other, a gentleman's club of officers whose success in the military and success in the civilian realm were as thoroughly intertwined as strands of DNA. Today Switzerland's military and civilian worlds are decoupling.

Colonel Rudolf Wicki started flying jets for the Swiss air force more than 30 years ago, starting in the indestructible Hawker Hunter. "I flew them from '66 to '94," he says. "The best ever Hunter. We could have sold them for the same price as new." He shrugs. "Mostly they gave them to museums and the like."

Two engineering marvels: The Super Puma, able to lift a four-ton load, and a hundred-year-old rail viaduct crossing the Rhine.





On their way to flying an F/A-18 over the Alps, Swiss pilots must first fly Pilatus PC-7 trainers over Lake Maggiore.

Wicki is the commander of the pilot school at Emmen. He has the aura of a stern friar until he smiles, and then you see that the friar may have a streak of mischief. He trains only about a dozen novices a year, and they arrive at his school only after a long gauntlet of screening and evaluation. In Switzerland, you settle on flight early—applications go in at age 16. For males, it's one way to shape one's inevitable military destiny. For women, service is voluntary. But, Wicki explains, "Once in the system, she stays in the system. She becomes like a male." (About 10 percent of the 18,000 people in the Swiss air force are women, and some of these have joined the very small cadre of pilots, mainly in helicopters.)

Most years about 900 applications come in. These are winnowed by physical and psychological testing, the survivors given preparatory flying experience with the Swiss Air Club, which is led by the air force. "After the two courses, students have additional tests. Coordination. Five flights in the PC-7 simulator," Wicki explains, referring to the Pilatus turboprop that has been Switzerland's basic trainer since 1982. Candidates must also pass a "so-called social assessment by a 15-person board," Wicki adds.

Only the serious survive. They then undergo 15 weeks of basic training and five weeks of flying, with 12 flights in the PC-7 at Locarno. Thereafter, they have seven weeks of training in PC-7s and six weeks at noncommissioned-officer school before they are graduated as corporals. Only then do they proceed to training in jets.

The move to jets is a big commitment that not everyone is willing to make. It requires a further 18 weeks of training—in British Aerospace Hawks. Student pilots then move up to F-5Es and -Fs for another 21 weeks. Some of the Lo-

carno students skip the jets and move instead to transports, of which there are few—several Pilatus Porters, a few biz-jets, and, soon, a couple of middle-size cargo transports. Others go to helicopter school to fly Sud-Aviation Alouette IIIs and Aérospatiale Super Pumas, which have become important not just for the military but for rescue, firefighting, and humanitarian airlifts.

Students transitioning to jets go from Locarno, in the southeastern lake country, to Sion, east of Lake Léman in the valley of the Rhone, or come here, to Emmen. On this day, a couple of pilots who look about 13 crouch on the wing of a Hawk as their instructor—a tall fellow about their age with a bleached carrot top and earring—introduces them to the aircraft with which they'll spend the next 18 weeks.

Graduation is a watershed moment, for it is as fresh lieutenants that jet pilots must decide whether to opt for the militia—and perhaps a job as a Swissair pilot—or for a career as a professional military aviator. If they choose the latter, Wicki says, they are in for another three years, attending the professional pilot school at Dübendorf, where they qualify as flight instructors. Militia pilots stop flying at age 36, says Wicki, but professional pilots can continue flying jets until they are 55.

But times are changing. After 2001, pilots in the Swiss militia will be flying helicopters and transports, and only professionals will be in jet fighters. The Hornet is already restricted to professionals, who spend six to eight months training at bases in Payerne and Dübendorf, and in such foreign drills as Norka. The new airplane has become the heart of Swiss military aviation. The first increment of 34 Hornets, one supposes, is just the beginning.



A pair of Mirage IIIs takes off near an intersection of runway and roadway on the air base in Buochs.

Lieutenant Stefan Jäger, who on this day demonstrates the Hawk simulator to a visitor clinging to a catwalk behind his faintly illuminated cockpit, offers a case in point. He is just at the 800-hour mark, an instructor pilot in Hawks and F-5s. When he graduates from Dübendorf, he'll go to the Hornet. Will he stay on? "I think," he says, "I will do 10 years, then move on to Swissair."

The listening friar is inscrutable. Ten years is a sizable commitment. Yet he must wonder: Why just 10, when you are one of only about 160 professional military pilots in all the land?

Without a cold war to give some direction to the notion of threat, many Swiss have begun to wonder just what the armed forces protect them from. For their part, the Swiss military seems to find the slack in the new world order uncomfortable, and it is trying to redefine Switzerland's place in it. The new catch phrase is Security Through Cooperation, and it represents a stiff shot of Swiss politics: Without the possibility of nuclear war, there is no longer a reason to impose on the citizens the huge burdens of the past. Cooperation with other nations is the road back to stability.

"We face the same problems as France, Germany. We have things like Yugoslavia," explains Brigadier Paul Kälin, the Swiss air force chief of staff. "You think crisis management. In the long term, we always have to be ready to defend the country. We don't know what happens. But nobody is able to build up an armed force in..." and he snaps his fingers.

Kälin is a compact, middle-aged man, dressed in a blue business suit. He is also an interesting example of how the system works here, where the professional officer corps is filled not from a Swiss West Point or Air Force Academy (there is none) but from the militia. In the early 1980s, after 32 years as an electrical engineer, he decided to jump from the militia to a full-time military career. His office, in what people jokingly call "the Pentagon," a six-story cruciform structure in Bern where the air force occupies one floor, is adorned with diplomas and trophies, including a

certificate from the Air War College in Montgomery, Alabama.

"During the cold war," he says, "we were really prepared to fight. Now you have to think in a different way. You have to talk to your neighbors. We are neutral, we will stay neutral."

Neutrality with an attitude can take many forms. Swiss soldiers could escort Swiss products through Eastern Europe in 1919, and it was perfectly okay for Switzerland to join the League of Nations in 1920—but also okay to bail out eight years later, after the league's efforts to sanction Italy failed. The Swiss greeted the advent of World War II with symmetry: insistence on neutrality plus general mobilization. When the war ended, they celebrated

like victors, which, in a sense, they were.

The Swiss have sent military observers along the armistice line in Korea since 1953, and they are abroad today in the Middle East and some rough corners of the former Soviet Union. Neutrality was flexible enough to allow the Swiss to endorse economic sanctions against Iraq and grant transit rights for equipment and personnel heading for NATO-led multi-national forces in Bosnia, where a Swiss logistics unit serves. It did not allow overflights of NATO combat aircraft en route to the Balkans, but did allow Swiss air force teams, with Super Pumas, to help out in Albania.

Kälin sees this kind of outreach as the harbinger of greater international involvement. In a year or two, he believes, the popular vote will put Switzerland into the United Nations, which it has supported but never joined. But he doubts that the Swiss will vote for more than bilateral ties to the European Union. There is simply no way a neutral Switzerland can join the European Defense System or NATO, but the country will continue its membership in international security organizations, like NATO's Partnership for Peace, that do not require from members a commitment of military assistance during war.

While peering outward, he says, the Swiss armed forces are also experiencing fundamental change—their ranks have been cut from 600,000 to 400,000, and more of these have chosen the military as a profession. The term of compulsory military service will probably be shortened so that men just hitting their stride in the private sector don't have to interrupt their careers. Yet Kälin envisions a much more active role in international peacekeeping.

Nothing is certain. Like California, Switzerland is liberal in its use of referenda. All it takes is 50,000 signatures to secure a national vote on anything the government wants to do, and all constitutional amendments are voted on by the people, not parliamentary representatives. It means nothing can be done without the approval of the governed—and thus nothing can be done quickly. "We have to do anything in Switzerland step by step," Kälin explains. "Convince the population. That's the way it should be. Even the best idea—in Switzerland—needs time."

As he speaks, referenda are gathering like alpine thunderstorms. One will determine whether troops will be allowed to go overseas armed for self-defense and training. Another wants to replace the militia with a professional force, a change that Kälin and many others deplore. "A militia army is not so ready as a professional army," he says, "but a professional army is a little bit a closed society." Still, the idea has a good deal of popular momentum.

"A group wants Switzerland without armed forces," says Kälin. "At the end of the year, the government sends a report to parliament. The popular vote may be in 2002." Leading up to that referendum, the army and air force are making their case to the people. "In Switzerland, you have to communicate with the population every day," says Kälin. "Drop by drop. You have to explain the true, the reality. You see the feelings of the Swiss population. You see the eyes."

On this day in Sion, the entire air force inventory is on the apron, wing to wing: a Super Puma, an Alouette III, an orange Pilatus PC-7 turbo-trainer, a yellow Pilatus PC-9 trainer, a Porter utility aircraft. A quarter-mile down the taxiways, Hawks and Tigers are in their boxes, along with a Mirage III with its chin drooping, revealing cameras. A Hornet is displayed in an *Unterstand* nearby. An Alouette putters up and down the line, with troops demonstrating hoists and rappelles. Now and then a flight of four Tigers blasts up the valley, returning half an hour later to make a low pass and land.

There are static displays of every known truck and fire engine and jeep, dioramas and videos. A trailer parked outside one hangar is labeled F/A-18 Shop, and offers Hornet posters, T-shirts, gimme caps, post cards, and other memorabilia. The event draws several thousand people, who

arrive in cars and chartered buses from as far away as Geneva. Some are attended by young pilots in flightsuits showing mom and dad what the air force is like. The eagerness of the pilots reminds me of Major Beat Herger, the deputy commander of the Parachute Long-Range Reconnaissance School whom I met at Locarno. Herger, about 40, trains parascouts, a special infantry that can operate 100 miles behind enemy lines for up to 30 days without resupply. Since 1978 this single company of about 100 men—only about 400 Swiss have qualified thus far—has been part of the air force's reconnaissance arm.

Parascouts apply early and stay late, mastering HALO (high altitude, low opening) jumps, static line leaps a hundred meters off the ground, and such other skills as are needed to survive for a month among an enemy. Most of the parascouts wind up as militia, led by a small cadre of professionals. Like pilots, Herger and his lads must go abroad to find some of the harder edges of reality.

"We can't be part of NATO but we cooperate with other armed forces," Herger says. In 1999, he was part of the air force Super Puma team sent to Albania. They flew humanitarian missions out of Tirana, the big helicopters daubed with UNHCR (United Nations High Commissioner for Refugees). Herger didn't take a silenced 9-mm machine gun with him, but he went. "We didn't know what to expect." His eyes shine with excitement. "It was just great."

Among these skilled warriors, one senses a kind of longing, not for war, but to fight in a just cause—for a month of living dangerously behind enemy lines, a reason to let slip a Sidewinder, to engage. "We don't wait behind the walls until we see it coming in," Brigadier Kälin had explained. "Now we go out with our partners. It's new thinking. A revolution." And it is a revolution in plain view. —

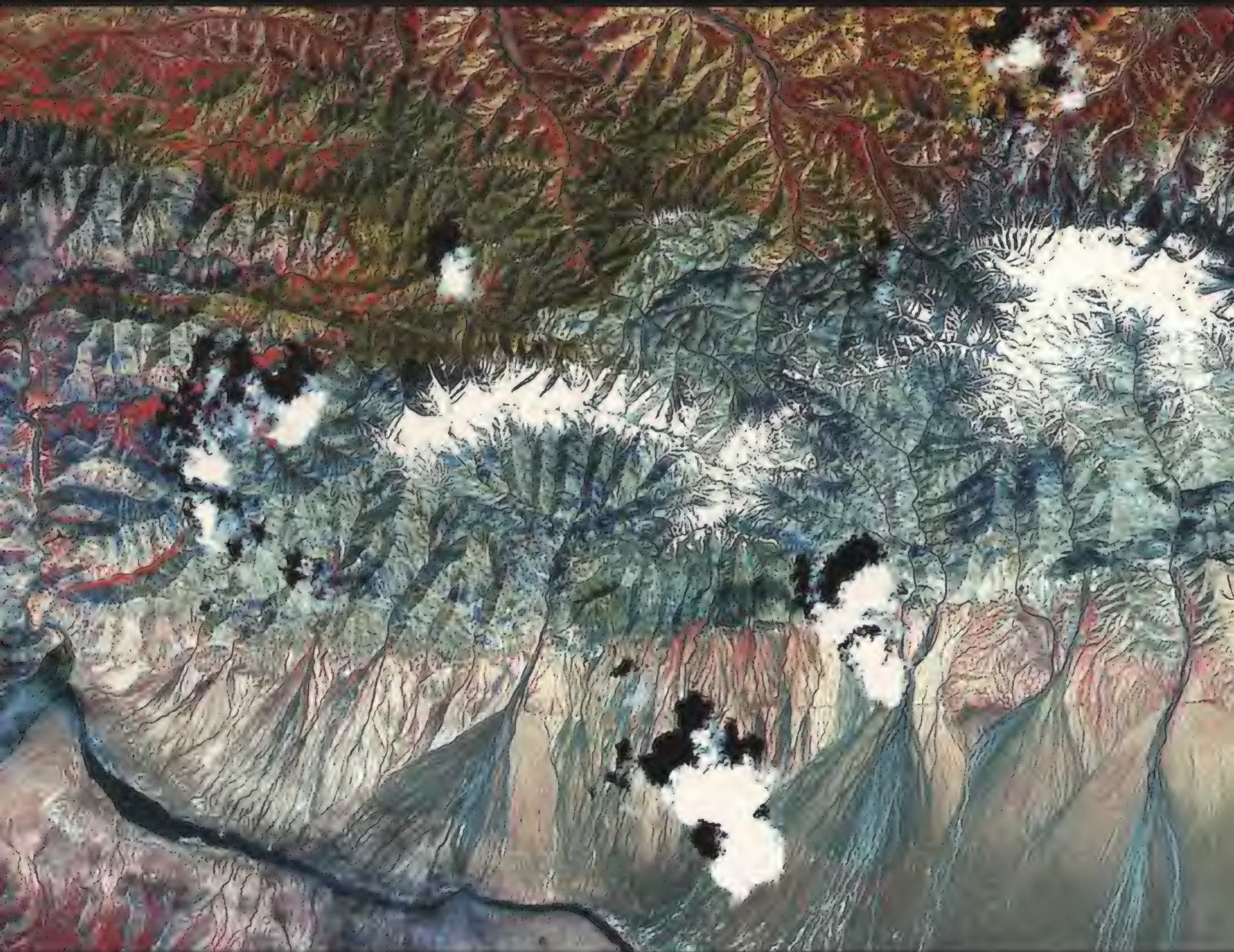
Though it looks like the top of the world, the Basòdino glacier at 11,000 feet is well below the 65,500-foot performance ceiling of the Mirage III.



by Tony Reichhardt

A new generation of
satellites zooms in
on a familiar planet.

TERRA



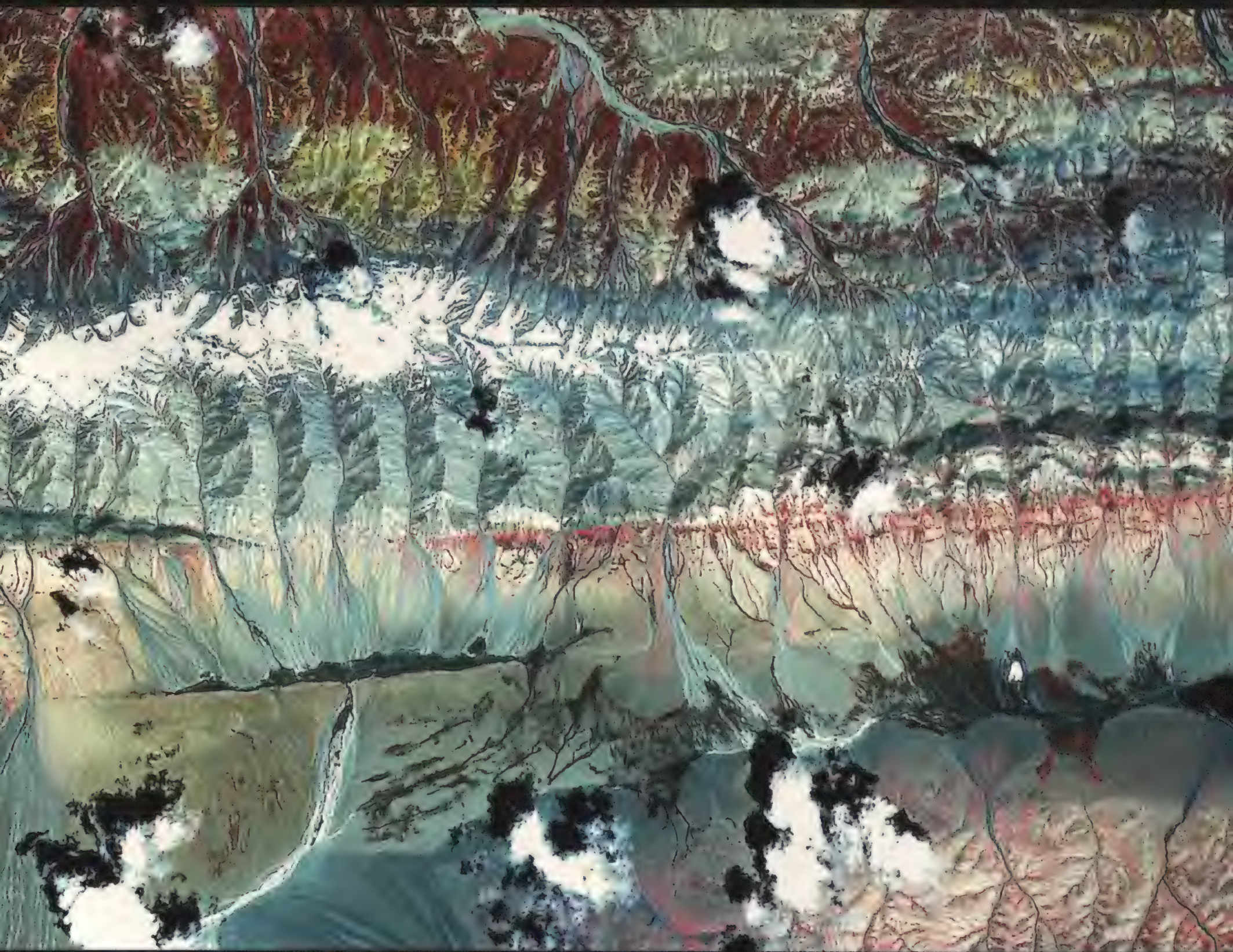
They're up there now, scanning the planet at all wavelengths, taking the measure of its shifting seas, winds, and landforms. Earth-viewing satellites have been around for 40 years, but none like these. A new generation of remote sensing spacecraft has brought unprecedented clarity and coverage to the study of Earth from space, and we now live on a continuously monitored planet.

In the 1980s NASA conceived of a grand "Mission to Planet Earth"—a fleet of large satellite platforms, each carry-

ing a suite of sensors that together would provide a long-term record of environmental change. It didn't turn out that way, mostly due to the multibillion-dollar cost. But a less expensive Earth Observing System (EOS) is reaching orbit, with the first major component launched in 1999.

Terra, as it's called, retains the original concept's Swiss army knife approach to Earth observation. Each of the five onboard sensors has its own specialty. A versatile spectrometer called MODIS takes regional-scale pictures in 36

CONTRAST



NASA/GODDARD SPACE FLIGHT CENTER/MITI/ERSDAC/JAROS AND U.S. JAPAN ASTER SCIENCE TEAM

wavelengths. The multi-angle MISR has nine separate cameras—four pointing forward, one straight down, and four looking backward—so that hard-to-see phenomena like atmospheric haze can be photographed in different angles of illumination. ASTER, the one Japanese instrument on board, is Terra's zoom lens; its high resolution is suitable for a range of tasks, from studying glaciers to tracking changes in land use. MOPITT is tuned to the infrared signatures of pollutants in the lower atmosphere, and CERES measures

Terra's zoom lens, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), captured this view of the Kunlun fault in northern Tibet last July. The image combines visible and infrared data and shows, among other details, the shadows of passing clouds. The fault line is marked by lines of vegetation, which appear red.

global radiation to help answer the critical question of what role clouds play in global warming or cooling.

Documenting global change is in fact the main quest of Terra and the rest of the new satellite sensors. They watch for signs that coral reefs are dying, that snowpacks are melting, that forests are disappearing, or shorelines are shifting. More importantly, they collect fundamental data—trillions of bytes' worth—revealing the complex interplay

of land, air, ice, and water driving our planet's weather.

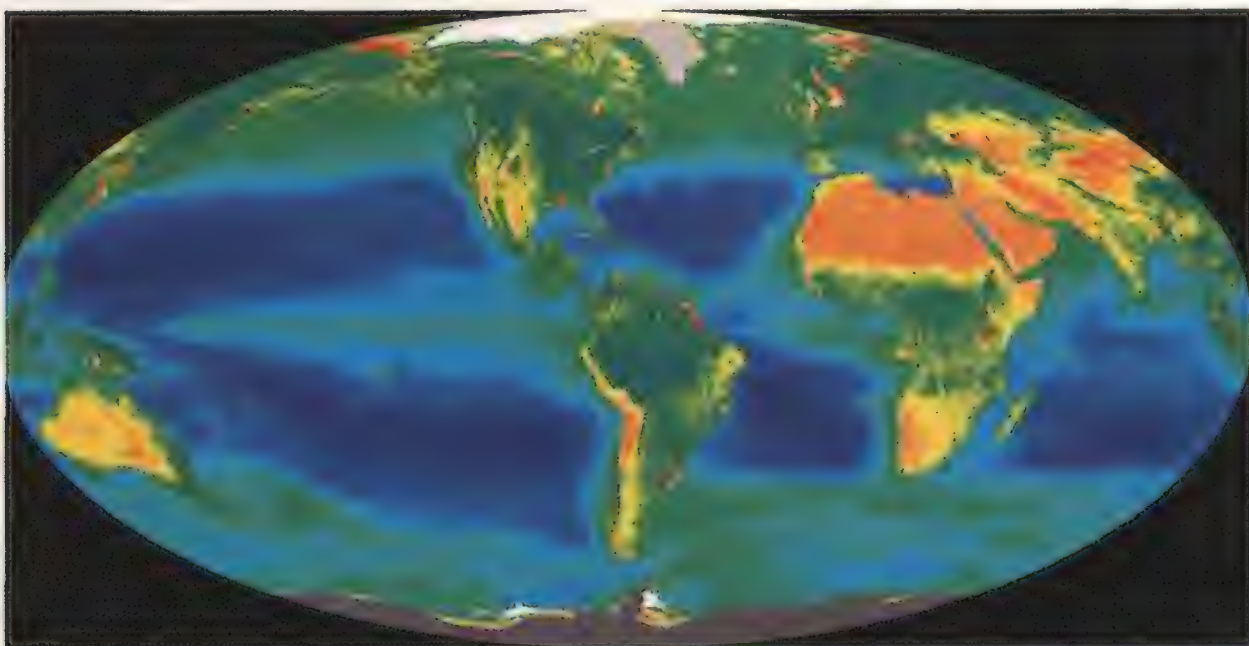
Terra will be followed later this year by the second large EOS platform, Aqua, which will focus on the atmosphere and ocean. By the end of 2003, some two dozen EOS satellites of varying size and scope will be in space. Add the data from non-EOS projects, like the Shuttle Radar Topography Mission, which last year mapped 80 percent of Earth's surface in 3-D, and Earth scientists are happily

Central Oregon's Cascade region shows the scars from widespread logging in this false-color image from the Japanese ASTER instrument, which is on Terra. This view combines red, shortwave infrared, and near-infrared light detected by the satellite. Snow-covered mountains to the east appear blue, forests are green, and clear-cut areas are orange-pink.

ASTER, the only Terra sensor that can match Landsat 7's 15-meter resolution, is designed to study thermal (heat) emission and reflection from the land, yielding detailed maps of surface temperature. The maps enable scientists to investigate problems ranging from deforestation to urban growth to soil erosion. The satellite can "revisit" any target to detect change over time, with visit intervals varying from 4 to 16 days. ASTER scientists plan eventually to publish a single, cloud-free composite image showing the entire land surface of Earth.



NASA GSFC/MITI/ERSDAC/JAROS AND U.S.-JAPAN ASTER SCIENCE TEAM



SEAWIFS PROJECT, NASA GSFC AND ORBIMAGE

The living Earth is revealed in this image, compiled from data taken over a period of three years by the SeaWiFS (Sea-viewing Wide Field-of-view Sensor) instrument on the commercially owned OrbView-2 satellite. The SeaWiFS detects the spectral signature of chlorophyll-bearing plankton, tiny marine organisms that are responsible for about half of Earth's primary biological production. Red areas in the ocean are highest in chlorophyll, yellow-green are intermediate, and blue-violet are the lowest. The ocean data represents a three-year average from September 1997 to August 2000. Land vegetation is based on data taken in July 1998, with dark green showing areas of dense growth and yellow-brown showing the absence of plants.

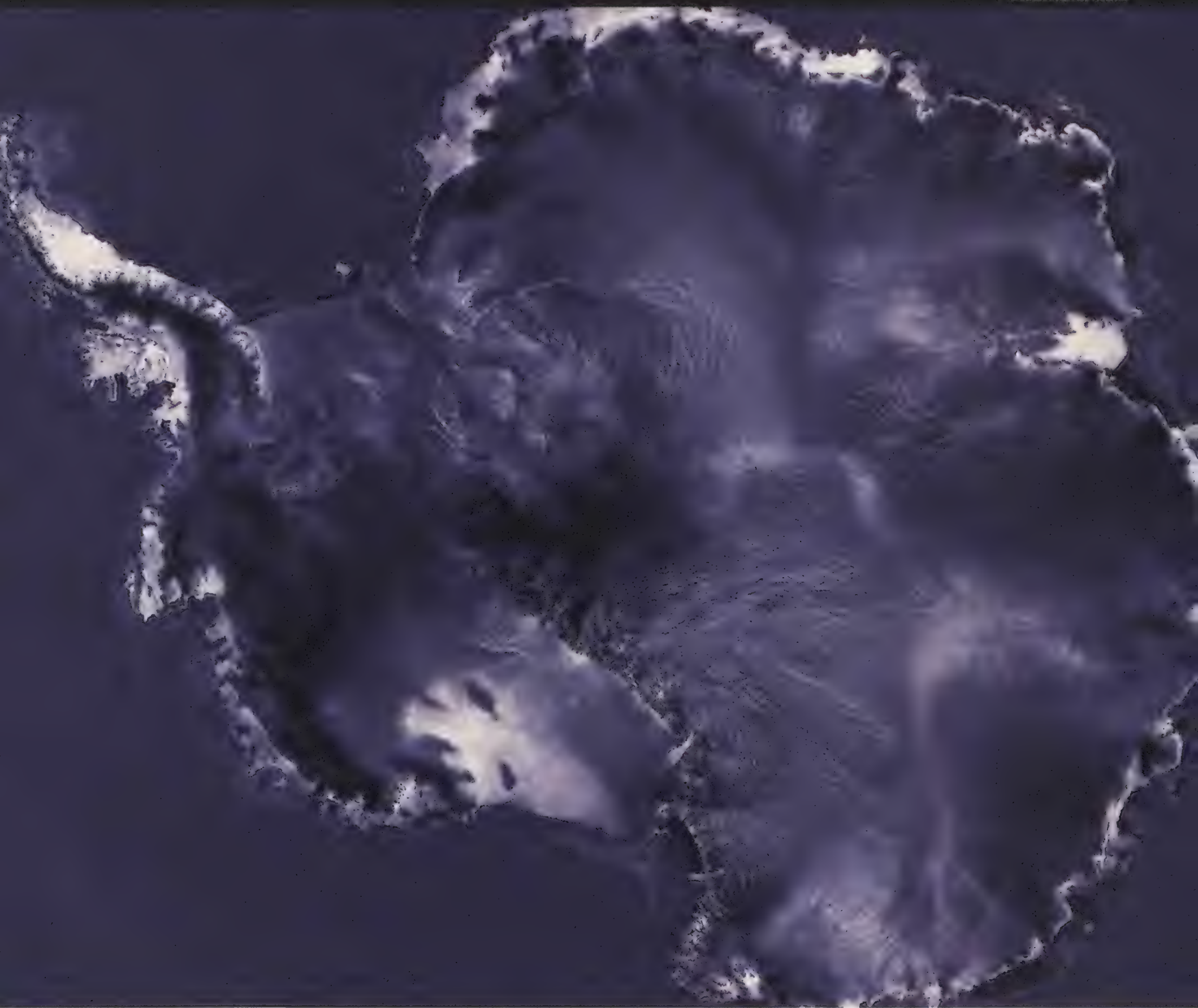
swamped with information. "These days there's so much data around that you can't possibly look at it all," says Alexander Goetz, who heads the University of Colorado's Center for the Study of Earth from Space.

More is on the way. With the launch of the EO-1 (Earth Observing 1) technology-testing satellite in November, NASA has made its first foray into space-based hyperspectral imagery, which sees in more than 200 wavelengths

instead of the few bands covered by older satellites like Landsat, and lets scientists better characterize surface materials based on the way they reflect or absorb light. The first commercial space images with one-meter resolution have already hit the market, with more sharp-eyed competitors on the way.

For students of planet Earth, the view is getting better all the time.

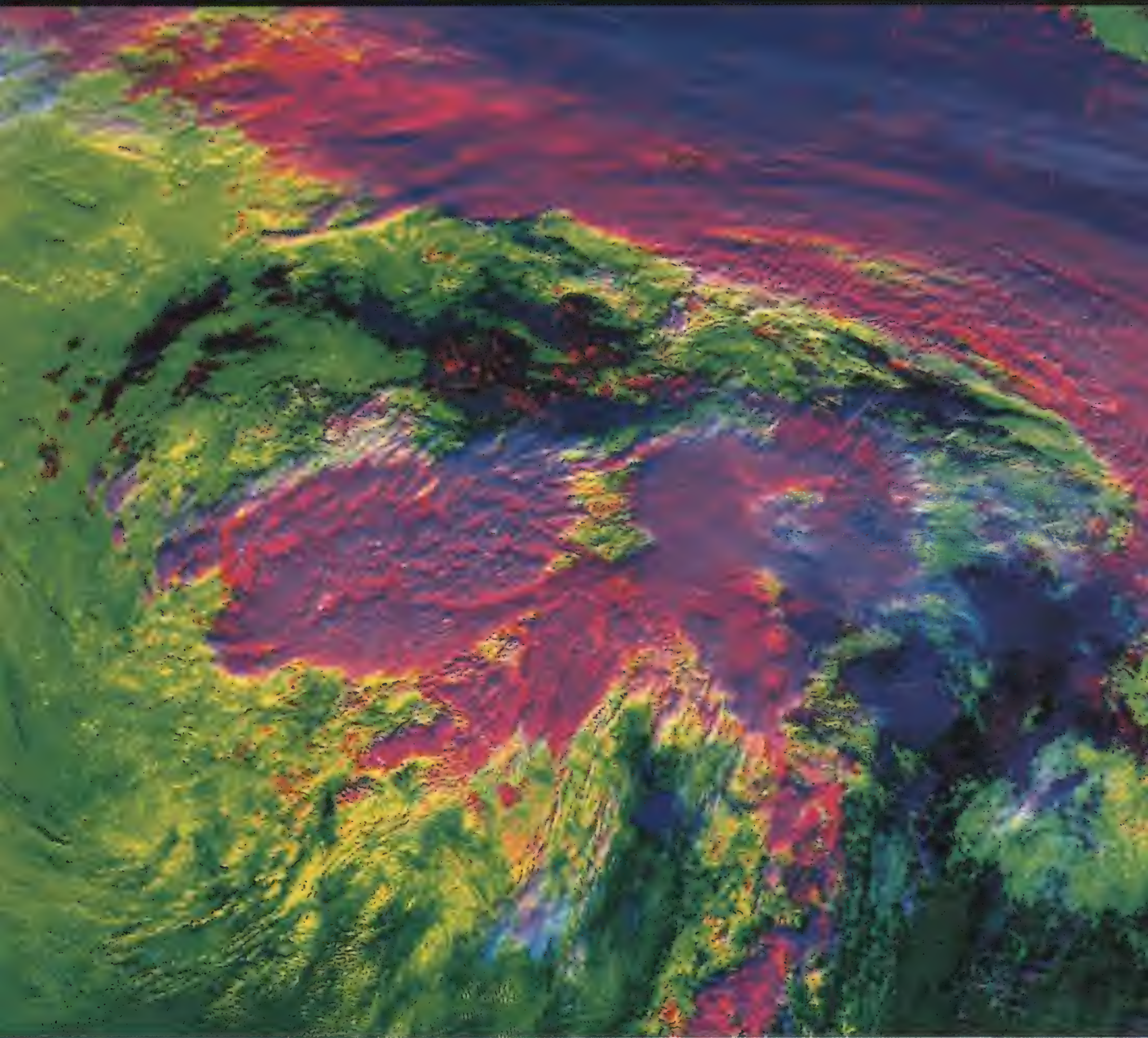
CANADIAN SPACE AGENCY



Because radar imagers can view Earth day or night, even through clouds, Canada's RADARSAT-1 needed only 18 days to produce this exquisitely detailed map of Antarctica.

Compare that to how long it took to make the previous best cloud-free satellite map of the continent, assembled from pictures taken by weather satellites over the course of 13 years. The

Radarsat images, gathered in October 1999, are being used by scientists to study previously unexplored features, including 500-mile-long ice streams flowing from the continent's interior.



Information on clouds is vital to understanding global climate change, so clouds are a primary target for NASA's Earth Observing System. In this view of the Great Lakes region, taken by Terra's Moderate Resolution Imaging Spectrometer (MODIS), cloud composition and altitude are revealed by how the clouds emit or reflect radiation. Pink areas in the false-color

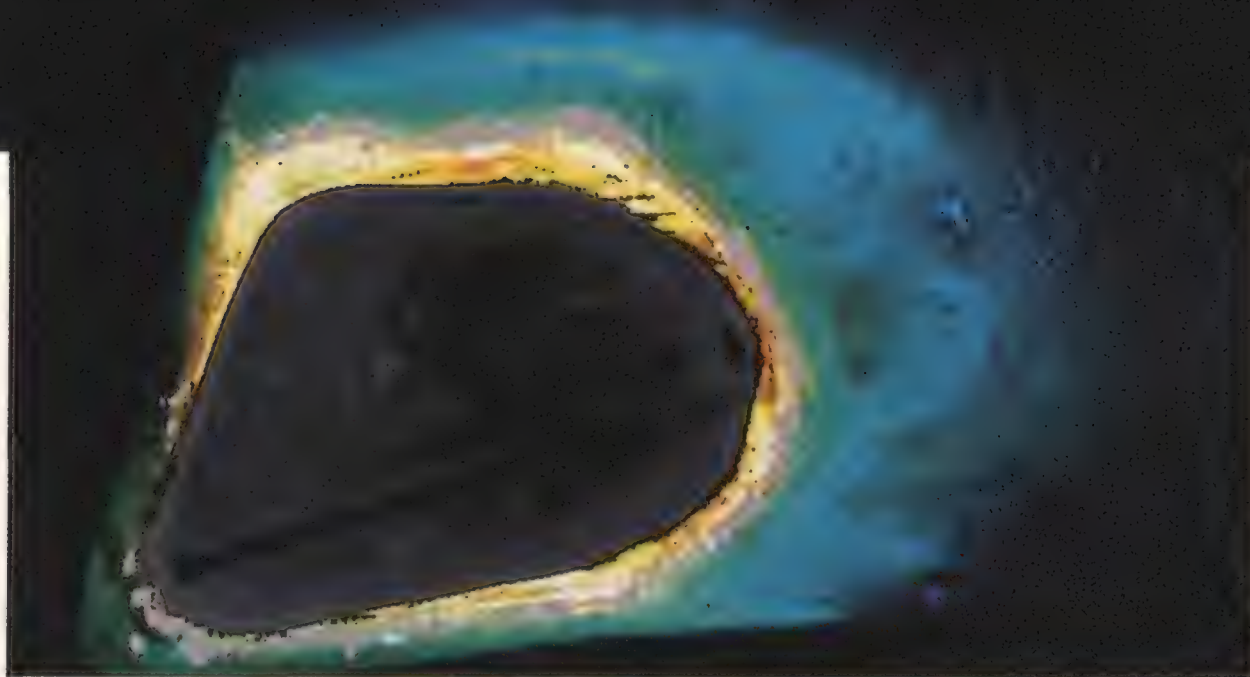
image show colder, higher clouds containing snow and ice, while green areas are lower clouds containing liquid water.

The versatile MODIS will fly on both of the first two large EOS platforms—Terra and the soon-to-be-launched Aqua—and is the workhorse for climate change research. MODIS extends and improves on measurements that have been made

by two key weather satellite instruments, the Advanced Very High Resolution Radiometer and the Coastal Zone Color Scanner. The new sensor scans the entire surface of Earth every two days. Data from MODIS already has been put to wide use, from monitoring fires in the western United States to documenting the biological productivity of the world's forests.



LIAM GUMLEY, UNIVERSITY OF WISCONSIN-MADISON/TERRA PROJECT



SPACEIMAGING.COM

National Oceanic and Atmospheric Administration (NOAA) researchers assessing the health of shallow-water coral reefs in the Caribbean and Pacific were in the market for high-resolution pictures such as this view of tiny Baker Island, located 1,600 miles southwest of Hawaii (blue and yellow areas are reefs). So they turned to Colorado-based Space Imaging, owners of

IKONOS, the world's only commercial satellite currently returning one-meter-resolution photos. The company's Washington operations director, Mark Brender, says Space Imaging had identified many uses for its close-up imagery, but never guessed that scientists would be using the pictures to look 90 feet underwater. "That wasn't in our business plan," he says.

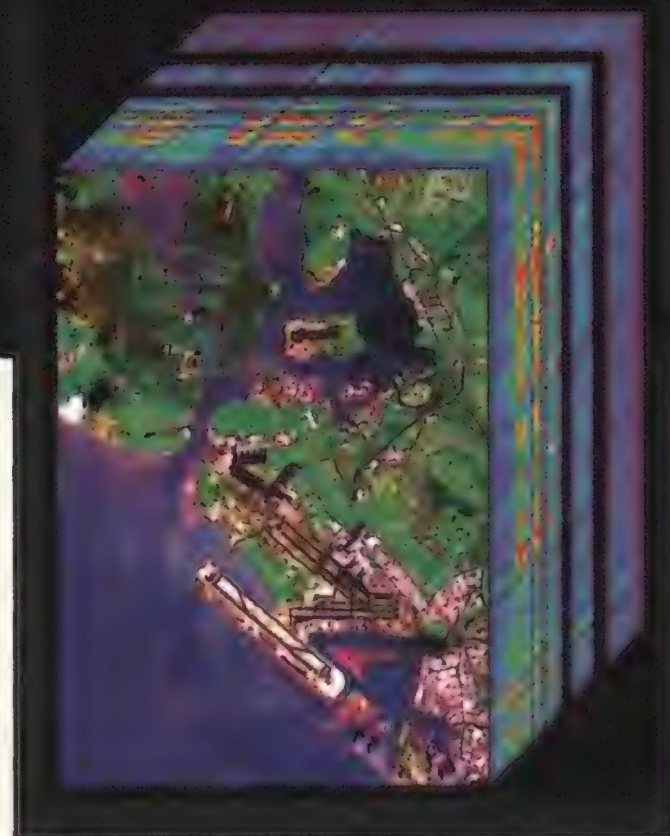
SEAWIFS PROJECT, NASA/GSFC AND ORBIMAGE



The SeaWiFS satellite, launched in 1997, is used primarily to monitor the biological productivity of the oceans. But its camera is also well suited to spotting fires from space, as in this view of a blaze in Greece during a hot, dry spell last July. SeaWiFS is perhaps the best example to date of government-industry cooperation in remote sensing. The satellite (also known as OrbView-2) is owned and operated by Virginia-based Orbimage, a subsidiary of Orbital Sciences Corporation. But it was the commitment to a long-term data purchase by NASA Earth scientists that led to the spacecraft's being built and launched in the first place.

This Landsat 7 view of Cape Canaveral, Florida, clearly shows the area's past and present launch pads, including space shuttle pad 39A, the rounded structure near the beach at top center. The first Landsat was launched in 1972, and its successors have been documenting Earth's changing surface ever since. The most recent in the series, Landsat 7, is easily the best. Not only are its pictures sold to scientists for a

fraction of past prices, but the archive of captured scenes is much larger. Landsat 7 also doubles the sharpness of its predecessors, with 15-meter resolution in black and white. And for the first time, the data is precisely calibrated to other satellite and airborne data, which "makes us more objective than we've been in the past," according to geologist and remote sensing specialist Alexander Goetz of the University of Colorado.



The next big thing in remote sensing, hyperspectral sensors return data across a continuous spectrum subdivided into 200 or more channels—as compared to a handful of separate, selected bands for traditional satellites like Landsat. This "datacube" shows the amount of information contained in a single hyperspectral image of Pearl Harbor taken by AVIRIS (Airborne Visible Infrared Imaging Spectrometer), an airplane-mounted instrument similar to the hyperspectral imager recently sent into orbit on NASA's Earth Observing 1 satellite. Each picture element—pixel—on the cube's face has its own spectrum, yielding a wealth of information on how the surface reflects or emits light. A slice through the cube in a plane parallel to the image would show the scene as it appears in a single narrow wavelength.

It used to be that only airplanes could return overhead images this sharp. But the view of downtown San Francisco (opposite) was taken by the IKONOS satellite from an altitude of 423 miles. (Note the Transamerica pyramid building at top center.) The computer-enhanced image adds four-meter-resolution color data to a one-meter-resolution black-and-white image to achieve sharpness without sacrificing realism. Space Imaging, which owns IKONOS, says that demand for the hi-res orbital photography is growing. Buyers have requested everything from photos of Mt. Ararat in Turkey (a team searching for signs of Noah's Ark) to pictures that a woman commissioned of her New York lake house. Apparently she wasn't daunted by the \$1,000 minimum for a targeted IKONOS "scene."

USGS/EROS DATA CENTER



the hammer

FOR EVERY AIRPLANE,
THERE'S A REGION OF THE
FLIGHT ENVELOPE INTO
WHICH IT DARE NOT FLY.

by PETER GARRISON *Illustrations by* JOHN MACNEILL



A little before midnight on September 29, 1959, a Braniff Airways Lockheed Electra was cruising at 15,000 feet between Houston and Dallas. Some of the 26 passengers may have been reading, but most probably dozed, lulled by the throb of four big turboprops.

Then came a different sound, a shaking that grew gradually until the interior of the cabin began to rattle and creak. Passengers sat up and looked around anxiously. The shaking lasted 30 seconds, becoming rapidly more violent and ending with the terrible shriek of tearing metal.

The Electra had lost its left wing. Parts of the airplane rained down over an area four miles long. Witnesses on the ground described a glow like a meteor—bright, then fainter, then bright again—a screaming sound like a jet engine, and a boom. They later identified a recording of a runaway propeller

as most similar to the sustained sound they had heard.

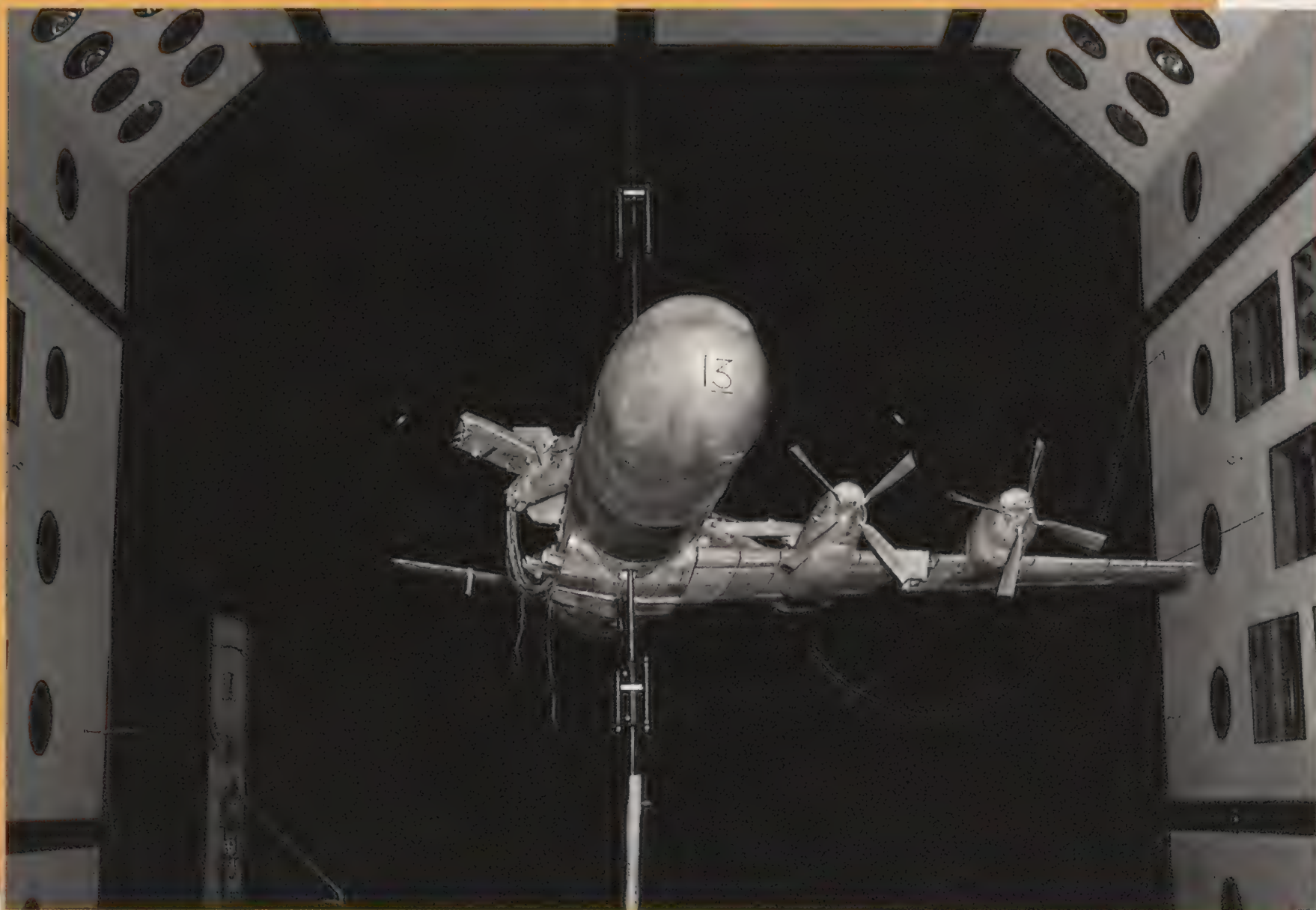
Accident investigators focused their attention on the failed wing's outboard engine nacelle, because scratches and tears in the metal indicated that the propeller and gearbox, mounted several feet ahead of the engine and connected to it by a long power shaft, had swung as much as 35 degrees out of alignment. But the sequence of events was baffling. Lockheed's engineers had, of course, anticipated that a propeller could shed a blade, throwing the engine out of balance and causing a catastrophic failure. But they had designed the nacelle to break away from the airplane before it could overstress the wing. Yet even though the wing had separated from the fuselage and the propeller and its gearbox had separated from the engine, the nacelle had remained attached to the wing.

The first hypothesis was that the pri-

mary failure had been caused by a wing overload, and the powerplant damage had occurred during the subsequent disintegration of the airplane. But it was hard to believe that this was a case of simple overload due to turbulence or pilot action. Wing failures in airliners were extremely rare—only five had occurred in the previous 40 years—and if the Electra had a structural weakness it would have surely turned up in Lockheed's rigorous ground- and flight-test programs or in Eastern Airlines' thousands of hours of high-speed, low-level operations along the eastern seaboard. This looked more like the work of the mysterious and deadly demon called flutter. But no plausible flutter mechanism could be found to explain this accident.

Flutter has always been aviation's dirty little secret. Seldom reported and little understood, it occupies one

After two Lockheed Electras fell from the sky in pieces in 1959 and 1960, engineers put an elaborate 1/8-scale model in a wind tunnel to induce a phenomenon called propeller-whirl flutter, which, theory said, had caused the aircraft's wing to fail. One result of that test is shown below.



NASA LANGLEY (2)



"Galloping Gertie," the nickname for the Tacoma Narrows Bridge that undulated when the wind blew across it, broke up spectacularly in 1940 when a steady 42-mph wind set it rocking. A cable snapped, creating an imbalance, and flutter, with a very slow natural frequency and a very large torsional, or-twisting component, brought it down.

of those dimly lit and unsafe places that decent people prefer not to visit. The idea that an airplane could shatter—disintegrate—for no reason other than its own motion through the air—better to let sleeping horrors lie.

Compared with most other concepts in aeronautics, flutter is obscure and difficult to grasp, but there are examples of the phenomenon in everyday non-aeronautical life. An out-of-balance tire is one; it begins to vibrate at a certain speed as the car accelerates; at some higher speed the vibration subsides. What is happening is that when the tire's natural bounce frequency matches its rate of rotation, the wobble due to imbalance—which is always present—is amplified by the bouncing of the tire on the road. Another ex-

ample is a child on a swing: The amplitude of the pendulum motion increases when the motions of the torso and legs are properly synchronized with it, but not otherwise.

We use different terms for different instances of the same underlying phenomenon. When we talk about riding a swing, we call it "pumping"; when it's a vibrating tire, we say "resonance" or "sympathetic vibration." When the subject is music, we speak of harmony or being in tune (see "Tuning Up for Disaster," next page).

"Flutter" is the term used for synchronized vibration when it takes place in a flexible structure moving through a fluid medium—for instance, an airplane in flight. It occurs when two regular, rhythmic motions coincide in such

a way that one feeds the other, drawing additional energy from the surrounding flow. In airplanes, there are countless combinations of vibrations that can join forces in this way.

Each component of the airplane has, like a guitar string, a natural or fundamental frequency, plus a whole family of harmonics—integral multiples of the fundamental frequency—of diminishing strength. A classic case of wing flutter might combine wing bending—a flapping motion of the entire wing—with either wing twisting (torsion) or the flapping of an aileron, which has the same lift-amplifying effect as twisting the wing does. But there are myriad other possibilities involving all sorts of combinations of bending, twisting, and flapping, each with its own fundamental and harmonic frequencies, in wings, tails, fuselages, control surfaces, and trim tabs.

Out-of-balance tires seldom lead to structural failure of the car because automobile suspensions are vastly overbuilt for the loads they normally encounter. But airplanes, which must be kept as light as possible, are not superfluously stout. They are capable of failing with explosive suddenness when flutter sets in.

One of the most famous and spectacular cases of destructive flutter befell not an airplane but a bridge. When the Tacoma Narrows Bridge in Washington, then the third longest suspension bridge in the world, opened to traffic in the fall of 1940, it had already acquired the nickname Galloping Gertie because it heaved rhythmically and visibly when the wind blew. In fact, people repeatedly crossed the bridge just to enjoy its roller-coaster-like undulations, which were considered harm-

A 1/4-scale F-16 flutter model tested numerous "stores" configurations—bombs, missiles, fuel tanks—in the world's premier flutter testing facility, the Transonic Dynamics Tunnel at NASA's Langley Research Center in Virginia.



less. On November 7, only six weeks after the bridge opened, a steady 42-mph wind was blowing along Puget Sound. The slender span began its dance. Then a cable near mid-span snapped, creating an unbalanced condition. Soon the bridge was undergoing twisting, heaving, and swinging motions of an incredible magnitude. These continued for more than half an hour before the center span fell into the water—long enough for an amateur filmmaker to record for posterity the astonishing spectacle of the giant bridge writhing like a wounded snake as a terrified motorist abandoned his car and ran for his life (see the bridge in action at www.airspacemag.com).

Even today the exact mechanism of the flutter of the Tacoma Narrows Bridge is disputed. The fact that half a century of reflection and analysis has not settled the question gives some indication of the abstruse nature of flutter itself. The case of the Lockheed Electra might have remained similarly mysterious—the Civil Aeronautics Board, precursor of today's National Transportation Safety Board, was ready to throw in the towel and label the crash "unexplained"—had not a second accident, almost a carbon copy of the first, occurred. This time it was a Northwest Orient Electra flying from Chicago to Miami in March 1960 that broke up in flight over Indiana, killing 63. The flight was known to have been operating in an area of severe turbulence, and the failure might have been attributed to structural overload had the damage signatures around one engine nacelle—this time the right outboard engine rather than the left—and the distribution of parts in the debris field not been so similar to those in the previous accident.

General Motors' Allison Division, manufacturer of the Electra's engines, dismantled and minutely examined all eight engines from both aircraft. NASA weighed in with detailed analyses of flutter modes that might occur if various structural failures had gone undetected in a wing or nacelle. Every path came to a dead end. All analyses found that the structure incorporated large margins of safety. Flutter, the only possible explanation, seemed impossible.

Then Lockheed structural dynamicist J. Ford Johnston had the idea of investigating the hitherto neglected contribution that might be made by small yawing deflections of the propeller. As pilots of propeller aircraft know from experience, the center of thrust of a climbing airplane's propeller shifts to the side of the downgoing blade. This phenomenon, colloquially called P Factor, occurs mainly because a component of the airplane's forward velocity is added to the speed of a downgoing blade and subtracted from that of an upgoing one. A similar phenomenon, rotated 90 degrees, naturally occurs when the engine swings to one side. Shifting the center of thrust flexes the engine mount, creating a new shift in the center of thrust and a new direction of flexure. As a result, a propeller and nacelle can vibrate continuously in a circular motion called "whirl mode" (see illustration, next page). Johnston suggested that whirl mode vibration might have initiated an unsuspected flutter mechanism.

As early as 1938, a study on powerplant vibrations had raised the possibility of propeller whirl inducing structural flutter. But the relative weights of engines and propellers, the stiffness of propeller shafts, and the engine power outputs that were typical in the late 1930s made it a practical impossibility. As Lockheed mathematician Robert Donham, who participated in the accident investigation, says today, "Probably nobody involved with the design of the Electra even knew the paper existed. Nobody thought about whirl-mode vibrations causing flutter."

Lockheed's flutter analysts reprogrammed their computer to include whirl mode, and the mechanism of the accidents began to emerge. By an unlucky coincidence, the whirl-mode frequency of the Electra's big four-blade propellers happened to match the flapping frequency of the wing. The propellers, like the child driving a swing higher by small movements of her body, had eventually caused the wing to flap so violently that in 30 seconds it broke at the root without the propeller whirl ever overloading the nacelle structures.

Microscopic examination of fractures in the wreckage of the two airplanes revealed engine mount damage

Tuning Up for Disaster

When a musician wants to ensure that his instrument is playing at the proper pitch, he compares a note to that of a vibrating tuning fork. The tuning fork is a reliable standard because it always vibrates at exactly the same frequency and therefore hums at only one pitch, regardless of how you hold it or how hard you strike it.

When, hundreds of years ago, clockmakers needed a reliable way to measure small units of time, they turned to the pendulum. As Galileo had discovered in 1582, and as a child on a swing may notice, a pendulum of a given length always oscillates with the same frequency, regardless of the arc through which it swings.

The utility of tuning forks and pendulums as standards is due to a common physical phenomenon. A great many objects and structures have what is called a natural frequency of vibration. The natural frequency depends on the mass of the moving object and the stiffness of the "spring" that makes it oscillate. In the case of the pendulum or the swing, the spring is gravity, and in the case of the tuning fork, the elasticity of the steel. All elastic systems have this property, including the structures of airplanes. If you timed the up-and-down motions of an airliner's wingtip as it flies through rough air, you would find that its frequency is constant, regardless of the strength of the turbulence, because an airplane's wing is like a huge, very-low-frequency tuning fork.

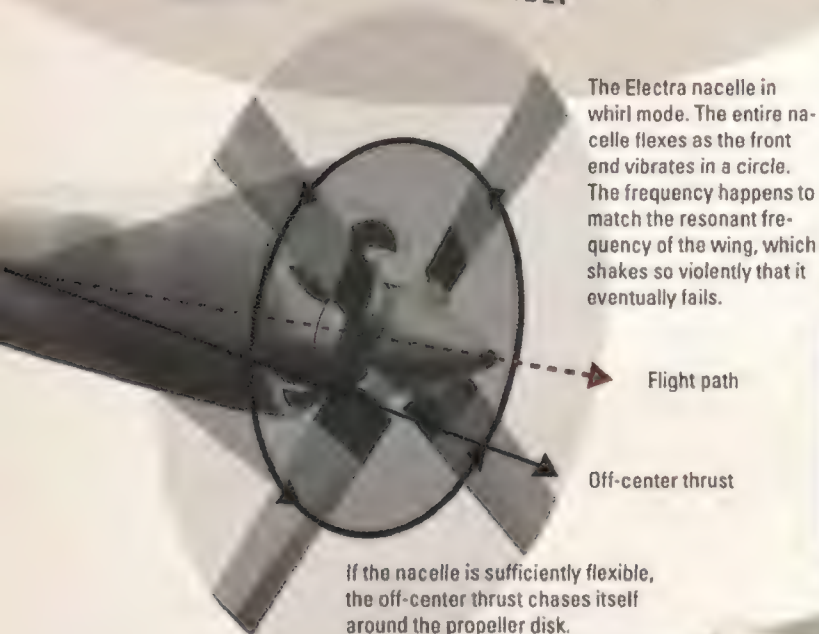
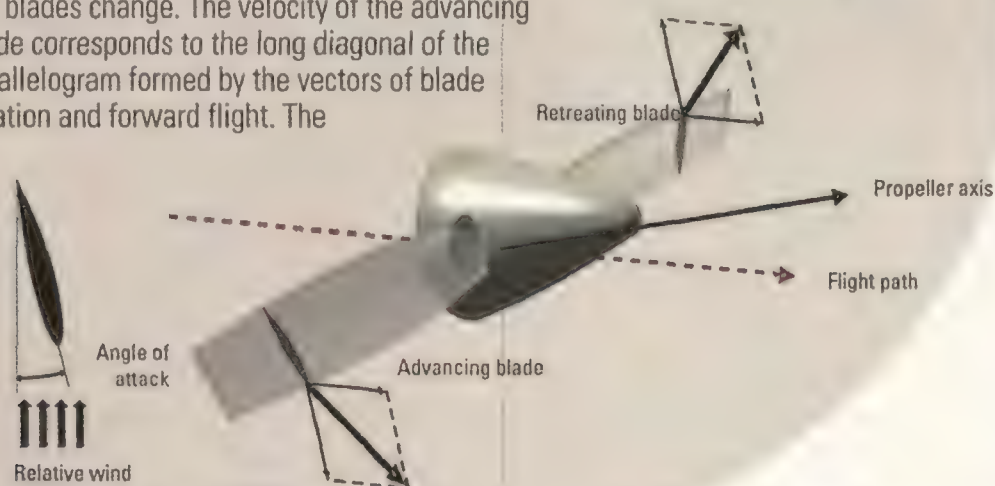
An object is said to "resonate" when it begins to vibrate in tune with some other vibrating object. A sufficiently loud sound at 440 cycles per second, for instance, will set a tuning fork in the key of A to humming. Resonance occurs because it is easy to make things vibrate at their natural frequency, but difficult to make them vibrate at any other frequency.

Resonance is at the root of the phenomenon of flutter in aircraft. Just as a crystal goblet, set to vibrating by just the right "forcing frequency," may shatter, a structure on an airplane, set in motion by another structure whose natural frequency is very nearly the same, may vibrate so violently that it breaks.

Whirl-mode Flutter

Propellers are rotating airfoils. When you tilt a propeller, one blade is flying more into the wind, and the opposite one is retreating from it. The angle of attack of the advancing blade is slightly increased, and that of the retreating blade slightly reduced. At the same time, however, the speeds of the blades change. The velocity of the advancing blade corresponds to the long diagonal of the parallelogram formed by the vectors of blade rotation and forward flight. The

velocity of the retreating blade corresponds to the short diagonal. Since aerodynamic forces are a function of the square of speed, but only of the first power of angle of attack, the speed component is the more important. The center of thrust shifts toward the advancing blade.



Sympathetic vibration

Two violin strings tuned to different frequencies; bow one and the other remains silent.

Strings tuned to the same frequency; bow one and the other vibrates in sympathy.

The whirl-mode frequency of the Electra propellers was tuned with the primary wing bending mode. Sympathetic vibration led to structural failure.

that had preceded the inflight breakups. The cause of the earlier damage was uncertain—in one case a hard landing was suspected—but Lockheed redesigned the engine mounts and no Electra ever suffered from whirl-mode flutter again.

Flutter is all about stiffness, not strength; even the strongest structure may fail if it flutters. In general, structures that are light and stiff vibrate more rapidly; they are said to have higher natural frequencies. Structures more massive or less stiff have lower frequencies. The usual treatment for a flutter problem is to raise the natural

frequency of one structure by stiffening it, but sometimes the opposite approach is used: lowering a frequency by the careful placement of damping weights. The essential thing is to eliminate coincident frequencies in structures that can feed energy to one another. A wing that is very stiff in bending should be made “softer” in torsion, and vice versa.

Flutter specialists speak a language incomprehensible to ordinary engineers. For a long time, the designers of aircraft structures confined their attention to static loadings and ignored dynamic loading. The late Raymond Bisplinghoff, a specialist in aeroelas-

ticity whose career included top-level roles at the Massachusetts Institute of Technology and NASA, recalled his time at Wright Field's Aircraft Laboratory during World War II in Hugh Flomenhoft's book *The Revolution in Structural Dynamics*: “The design-desk officers would frequently fly into a rage when told by an apple-cheeked youngster that weight or speed restrictions had to be added to their airplane to prevent aeroelastic problems. I was thrown out of their offices on an almost daily basis and frequently told...that flutter was a figment of my imagination.”

At the time, the tools available for the mathematical analysis of flutter were primitive, though, as has often been the case in the history of aviation, theoretical understanding was far ahead of practical application. Problems that today take barely a split-second's attention from a desktop computer then required weeks of manual computation on battalions of mechanical calculators—what the late physicist Richard Feynman once termed the “many females” approach to mathematics. Alternatively, analog computers, in which physical objects were simulated by electrical circuits with similar resonant characteristics, were programmed with data collected by shaking airplanes with variable-speed electric motors swinging unbalanced weights. Bisplinghoff recalled pressing his head against the underside of vibrating wings to locate their “nodes,” the points that remained still while the wing vibrated.

Another approach to flutter analysis is testing scale models in a wind tunnel. This is tricky, requiring duplication in the proper scale of not only the geometry of the airplane but the mass and elastic characteristics as well. Since small structures tend to have higher resonant frequencies than large ones, wind tunnel models for flutter studies were originally built with wooden spars and rubber skins to lower their natural frequencies. Today, glass-fiber laminates are used because their flexural behavior can be tailored by changing the fibers' orientation.

The world's premier flutter-testing facility is the 16- by 16-foot Transonic Dynamics Tunnel at NASA's Langley

Research Center in Virginia, which provides its clients with empirical data that they use to fine-tune their computer models. It also provides occasional moments of excitement when a model actually flutters (see flutter in action at www.airspacemag.com). Sometimes, says TDT research engineer Don Keller, this happens only once per model, because afterward, "you are sweeping it up into a bag." Because the tunnel can operate at up to Mach 1.2, it allows engineers to explore the critical speed range, around the speed of sound, where the unpredictable behavior of shock waves creates a "transonic bucket" in which flutter is much more likely to occur. Even with the tunnel and extremely sophisticated

software, however, some flutter modes are elusive: "You can't predict them," Keller quips, "until they happen."

In the absence of detailed computer analysis or costly ground vibration testing, airplanes can be tested for flutter resistance in an ad hoc way. The late John Thorp, whose design career spanned the glory days from 1930 to 1960, called this "tickling the dragon's tail." Beginning at a low speed where the airplane was known to be flutter-free, the test pilot would accelerate by a mile or two per hour, then deliver a sharp slap or "pulse" to the control stick or the rudder pedal. He would pay careful attention to the immediate aftermath of the disturbance. Did the stick or pedal immediately return to center, and the airplane appear unperturbed? This was a "dead beat" response; it indicated that no tendency to flutter was present at that speed. The pilot would then increase speed by a small amount and repeat the test.

The seat-of-the-pants approach to flutter testing is possible for the same reason that an automobile tire that vibrates most severely at 60 mph starts shaking at 55 and stops at 65 or 70. The tendency to flutter does not usually rise instantly to a maximum when one parameter or another—say, airplane speed—reaches a critical value. It normally ramps up gradually enough for speed increments of 1 or 2 mph to give the pilot warning of impending trouble. The pilot relies on the feel of the stick to warn him of diminished damping. The dead beat response softens; the stick wobbles once or twice before returning to center. Sometimes a control surface actually flutters with a low intensity, so the structure flexes but does not fail and the pilot, by slowing the airplane, can arrest the flutter.

Still, "usually" and "normally" must be added. On occasion, catastrophic flutter occurs at a speed only very slightly above a speed that was considered "safe," and sometimes even below it. Today, except in the lowest-budget flight test programs, sensitive electronic motion sensors and strain gauges measure and record vibrations that are triggered by a mechanical shaker rather than from the pilot's hand or foot. The slightest decrease in damping is instantly detected. Nevertheless, testing

Rocket Science

The Saturn V rocket experienced a novel and unexpected kind of structural resonance. The five first-stage engines were ignited at 0.3-second intervals, the center engine first, followed by the others in symmetrical pairs. Each ignition sent a jolt through the rocket and built up tension in its hold-down mechanism.

On launch the hold-downs flipped back to release the rocket—and the 360-foot-tall, six-million pound monster might have crumbled on its pad if aeroelasticity analysts at Boeing had not discovered in advance that the rocket resonated in tune with the rhythmically timed additions of thrust. The "twang" of the sudden release would then make the fuel and oxidant, which accounted for 90 percent of the Saturn's total weight, settle downward in the gigantic tanks, stretching their thin aluminum skins. The tanks would recoil like rubber bands, pumping the liquids back upward. The rhythmic bouncing of the entire fluid mass, which engineers nicknamed the "Ka-Doing-a-Doing-a-Doing mode," resembled the motion of a shaken water balloon. It produced structural loads well beyond the rocket's flimsy safety margins.

Various solutions to the problem were investigated, including baffles in the tanks—discarded as too heavy—and releasing the hold-downs before full thrust had been attained—too dangerous for the human occupants, in case the engines failed to attain full thrust. The eventual solution included altering the ignition timing and adding what came to be nicknamed the shoe-in-the-mud: a simple mechanical damper that slowed the rocket's initial acceleration after release, just as deep mud slows the extraction of a foot.

Early Saturn flight tests revealed that the bouncing of liquids in the tanks was also excited by the random vibrations of the engines. It launched a vicious cycle: pressures in fuel and oxidant lines began to fluctuate, throttling the engines up and down in time with the bouncing liquids. This "pogo effect" was cured by placing accumulators in the fuel and oxidant lines to damp out the pressure fluctuations.

Tests on an A-6 advanced composite wing with external stores shook things up in the Transonic Dynamics Tunnel in 1986. A model usually flutters only once, because afterward, says engineer Don Keller, "you are sweeping it up into a bag."



WASS/ARST



The Transonic Dynamics Tunnel hosted a 1/5-scale partial model of the V-22 Osprey in 1984. Today, a modified version evaluates tilt-rotor performance.

for flight flutter is no test pilot's favorite activity.

Until after World War II, structures were built as lightly as possible, and balanced and stiffened later as needed. Flutter problems were mainly attacked with empirical methods, often crude and sometimes quite drastic. Before the National Air Races in 1934, Steve Wittman's midget racer *Chief Oshkosh* repeatedly encountered severe but non-destructive flutter of a wingtip. It happens that short beams, like short piano strings or organ pipes, have higher natural frequencies than long ones. Therefore, after each test flight on which flutter was encountered, Wittman chopped a few more inches off the wing. Eventually the span was reduced to 16 feet, and the wing area from a minimal 78 square feet to a microscopic 42. The airplane landed awfully fast, but at least its wing was free of flutter.

William R. Laidlaw, former chief of the Structural Dynamics Section at North American Aviation, describes in *The Revolution in Structural Dynamics* a similar approach to controlling stabilizer flutter in the 1950s. During a test flight, an FJ-4 Fury, a carrier-based derivative of the F-86 Sabre Jet, lost more than half of both horizontal stabilizers to a flutter incident (the pilot managed to land safely). Engineers mounted a Fury tail assembly on a rocket sled at the Navy's test facility at Chi-

na Lake, California, and the flutter was duplicated. North American engineers considered various modifications to solve the problem, but finally settled on the crudest one: They sawed 12 inches off each end of the tail. A few months later, however, an FJ-4 shed its tail during a pullout from a high-speed dive, killing the pilot. The experts went back to work. They then discovered that putting a heavy load on the tail reduced its flutter margins. Another amputation, this time of a mere six inches, solved the problem for good.

Today, the practice of carrying armament and auxiliary fuel on external pylons, and the vast variety of possible combinations of external loads, make flutter analysis of modern fighters especially difficult. On the other hand, composite structures using care-

Boeing analyzed the effects of large engine cowls on the flutter characteristics of the 747 before its first flight in 1969.



fully controlled arrangements of graphite and other exotic fibers are much stiffer than aluminum or steel, and can even be made to deform under load in such a way as to reduce aerodynamic loads and therefore the chance of flutter.

Increasingly, new fighter and transport designs rely on electronics for stability and control, and in some cases for flutter prevention as well. The F-16, for example, is prone to a non-destructive wing flutter when carrying certain combinations of external loads. The wings flap out of phase—the left wing goes down while the right one goes up—imparting a rocking motion to the fuselage. Rather than modify the wing, researchers at the U.S. Air Force flight testing facility at Edwards Air Force Base in California programmed the fighter's electronic flight control system to sense the flutter and use the ailerons to oppose the wing's flexing. The fix, which will be incorporated in a flight control software upgrade scheduled for 2002, is indicative of what electronic flight controls can do. But they are not a panacea for flutter; the number of control surfaces available on an airplane's wings and tail falls far short of the number of possible flutter modes they can exhibit.

Discernible in the future are "smart" materials that expand or contract slightly in response to electrical signals. "They're like muscles," says Tom Noll, head of the aeroelasticity branch at NASA's Langley center. "They're normally in a neutral state, but they can be 'flexed' when extra stiffness or resistance to deformation is needed." Another possible weapon against flutter comes from the new field of MEMS—micro electro-mechanical systems. Thin surface overlays could raise thousands of tiny spoilers on an electrical command, disrupting airflow and preventing the aerodynamic augmentation that is fundamental to flutter.

Flutter analysis is often called a black science. Even though flutter is today well understood and largely preventable, it is still as formidable a foe as ever, and its malevolent unpredictability remains. "Some fear flutter because they do not understand it," said the famous aerodynamicist Theodore von Karman. "And some fear it," he added, "because they do." ✈



Smithsonian Study Tours

To request a Study Tours catalog call:
1-877-EDU-TOUR Toll-free
(1-877-338-8687)
(202) 357-4700 In the Washington, D.C. area

An educational benefit for Smithsonian Associate Members, Smithsonian Study Tours is the largest and most diverse program of its kind in the United States. Tours are designed to meet a variety of budgets and activity levels.



U.S. and Canada Land Tours

NEW—Georgia's Golden Isles,
March 25-April 1

NEW—Louisiana's Cajun and Creole Country,
March 25-April 2

NEW—American Visionaries,
April 25-29

NEW—Taos Art and Artists,
April 25-29

Arts and Crafts of the Pacific Northwest,
May 16-20

NEW—Walks at Point Reyes
National Seashore,
May 24-27

Spoletto Festival USA,
June 5-10

NEW—Dinosaur Encounters in Alberta,
June 15-21

International Tours

Rounding the Cape of Good Hope,
March 7-22

Kyoto Interlude,
March 9-18

Vienna Interlude,
March 27-April 4

Legacy of Sicily,
April 19-20

Tuscan Villa Retreat,
May 1-10

Venice & Veneto,
May 5-16

Italian Lake District Walks,
May 14-23

Glories of Northern Italy: Lombardy Emilia,
June 1-12

Irish Walks,
June 18-26

Scandinavian Summer Journey,
July 17-27

Hiking the Haute Route,
July 19-31

International Study Voyages

The Dutch Waterways and the
Belgian Countryside,
April 12-24

Provence: Cruising the Rhone River,
April 20-30

Australia's Kimberly,
April 27-May 11

Temples and Gardens of Ancient Japan,
May 7-21

Black Sea Cultures and Byzantine,
May 16-June 1

Crossroads of Civilizations of the
Western Mediterranean,
May 19-28

The Coast of Western Europe,
May 23-June 4

Danube River Journey,
May 30-June 12

French Waterways,
June 1-12

Cruising Norway's Coast,
June 1-12

Celtic Lands,
June 10-24

Norway's Fjords, the North Cape
and Russia's White Sea,
June 12-30

Journey into Russia,
July 10-24

Odyssey Tours

*Moderately priced tours with
multiple departure dates.*

Sojourn in Panama City,
March 21-28

France Through the Ages,
April 5-20

Legacies of England & France,
April 19-May 2

Images of Erie,
June 16-28

NEW—New Year's in Edinburgh,
December 26-January 2

**For a Smithsonian Odyssey Tour
brochure, call 1-800-932-8287.**



Explore North America by ship!

Call for a catalog!

Explore Alaska, The Top of the World
(Greenland to the NW Passage), Maritime
Canada, the Pacific NW, Columbia and
Snake Rivers or the Hudson River.

Resto

Desperate Journey | Junkers Ju 88

On August 31, 2000, the vertical fin of a Junkers Ju 88A-5 bomber with a swastika emblazoned on it broke the surface of the Kilsfjord, a lake near Kragerø, Norway, 60 miles southwest of Oslo. The Junkers had been ditched 58 years earlier during World War II, after its German crew stole the aircraft from the Luftwaffe's Number Three Advanced Combat Training School at Greifswald on Germany's Baltic coast with the intention of flying it to Great Britain.

That defection took place in the early morning of June 29, 1942. German fighter units in occupied Denmark and southern Norway were ordered to force the Junkers down or destroy it.

No explanation has been found for pilot Willi Voss' attempt to escape that night, but it clearly was a desperate gamble. He had no charts, his aircraft wasn't armed, and he could expect no mercy if caught. Only by skirting the German fighter bases in Denmark and coastal batteries in Sweden did he and

his fellow airman have a chance. If they made it that far, they would fly across the Kattegat Strait to Norway, then southwest to the country's tip, and finally across the North Sea to Britain.

Known as the "Star of the Luftwaffe" for its role as a fighter, bomber, and photo reconnaissance aircraft, the Ju 88 offered the airmen a cruising speed of 243 mph and a range of up to 1,550 nautical miles—enough performance, they hoped, to see them to safety.

Luck was with the two defectors at first. The fighters in Denmark were grounded by fog, low ceilings, and light rain. Luftwaffe radar operators could only watch as the Junkers entered the Kattegat and droned northward.

But it now seems clear that by the time daylight broke, Voss was in trouble. Had he grabbed just any aircraft from Greifswald without checking the fuel tanks? Was he experiencing mechanical problems? Whatever the cause of his plight, he began circling the Kilsfjord, then jettisoned the canopy and slid the Ju 88 across the water.

The frigid and oxygen-poor water of Norway's Kilsfjord preserved a rare Junkers Ju 88, which salvagers hoisted last August.



Two Norwegian girls vacationing in a cottage by the fjord grabbed a skiff and rowed to the aircraft, while a third started a fire in the cottage to warm the aviators. Voss was rescued and was soon wrapped in a blanket, but his unknown companion was lost. Voss was later captured and executed before being tried.

Peace eventually returned to the fjord, and the aircraft that had almost



The Ju 88 was a fast, multi-role bomber (top). A sonar search (above) was crucial to pinpointing the Junkers' location and positioning the recovery equipment. A remote camera confirmed the bomber, sitting on the bottom of the 185-foot-deep fjord, was intact.



ration



The bomber's metal skin had fared well, but the fabric on the Ju 88's rudder was badly deteriorated. When the cockpit surfaced, divers had to drain the wings before the rest of the craft could be raised (below).

carried Voss to freedom lay at the bottom of the Kilsfjord until it was discovered by scuba divers in the 1980s. But it wasn't until last year that the Forsvarsmuseet (Norwegian Armed Forces Museum) in Gardermoen could finance and organize a recovery operation, championed by air force major and curator Roar Glenne.

"It's taken years to get to this point," Glenne says. "We get no subsidies from the government or the military for our work. And all the help is provided by volunteers." The Saastad Diving Company, which performed all the salvage work, donated its services.

Before the recovery could begin, the aircraft's precise location and condition had to be confirmed by a remotely operated vehicle dispatched to the wreck. Then last August, using a TV camera, cutting tools, and mechanical

arms, salvage workers attached cables to the aircraft with a spreader bar to distribute the weight. Finally, on August 31, workmen raised the Ju 88 from the bottom of the 185-foot-deep fjord.

Aside from having lost its engines—which fell off because of corroded mounts—the Junkers was in remarkable shape because of its anodized aluminum structure and the oxygen-poor water at the bottom of the fjord.

Bullet holes later discovered on one upper wing surface may explain why Voss ditched. Was he bounced by fighters flying from a base in Oslo?

The answer may never be known, but perhaps the aircraft will reveal more of its secrets during the three to five years that its restoration at the Armed Forces Museum is expected to take. When the work is finally completed, the craft will be one of only



DOUGLAS HINTON (2)

three restored Ju 88s in the world.

As the aircraft breached the surface of the Kilsfjord last August, two elderly women quietly watched the proceedings from a small motorboat. As young girls, Aase Heibø and Ingrid Tuft had rescued Willi Voss and were the last to see the Junkers when it slipped beneath the waters of the fjord more than 50 years ago.

—Douglas Hinton

A large crane is lifting a massive, dark-colored rocket component, likely a Space Shuttle External Tank or Solid Rocket Booster, against a hazy, orange-tinted sky. The crane's arm and cables are visible, and the component is being hoisted vertically. In the background, a tall, slender structure, possibly a launch tower, is visible. The overall scene conveys a sense of industrial scale and aerospace engineering.

BAKON

BY JOHN SOTHAM

IT AIN'T PRETTY, BUT

IT SURE DOES WORK.



SCOTT PETERSON/LIAISON AGENCY



SCOTT ANDREWS

The Zvezda module for the International Space Station makes its way to the Proton launch complex. The module docked with the ISS on July 25, 2000.

A lonely, weathered marker standing next to Site 1 at Baikonur Cosmodrome informs visitors that this is where it all began. The marker, a simple concrete obelisk topped with a small metal sphere, commemorates the launch of Sputnik from this site almost 50 years and hundreds of launches ago. As you climb the steps from the Sputnik monument and stroll the short walkway to the launchpad, the concrete—worn away to expose rusted reinforcing bars beneath—crackles underfoot like a broken windshield. Paint ripples off the nearby blockhouses. Yuri Gagarin, the first space explorer, also launched from this pad.

And yet, among the ample reminders of the past, the future is very much alive at Baikonur. I was there as part of a press tour for Western and Asian journalists to cover the October 31 launch of U.S. astronaut Bill Shepherd

and two cosmonauts, Sergei Krikalev and Yuri Gidzenko, aboard a Soyuz TM-31 bound for the International Space Station. Their mission, as the first permanent crew of the outpost, would lift off from Site 1, adding yet another first to the lore of this place.

Baikonur lies 200 miles east of the Aral Sea, at about the same latitude as Seattle, and covers more than 4,500 square miles of Kazakhstan's immense desert steppes. For those of us covering the launch of Shepherd, Krikalev, and Gidzenko—dubbed the Expedition One crew—getting there meant a three and a half-hour ride from Moscow on a Yak-42 chartered by Energia, a company descended from Russian rocket patriarch Sergei Korolev's design bureau. Today, Energia, which is partnered with Western aerospace companies, manufactures Soyuz rockets both for manned missions and commercial launch. We were bused from central Moscow to Vnukovo-3 airport, which, like the city's three other major airports, is crowded with mothballed Soviet and Russian airliners, some still displaying the hammer and

The space station's first crew, Bill Shepherd, Yuri Gidzenko, and Sergei Krikalev, reports ready to fly. Their Soyuz rocket, pushed upright by its erector, waits at the launch pad (opposite).



MARK MILSTEIN/ATLANTIC NEWS SERVICE



Covering more than 4,500 square miles, Baikonur is an isolated outpost in the middle of the barren Kazakhstan steppes.

Paint peels from a rocket engine test stand abandoned in 1993.

sickle. The Yak tri-jet, which looks like a Boeing 727's little brother, still sported Aeroflot Soviet Airlines emergency cards in its seatbacks and was a pleasant ride, complete with flight attendants who plied the aisle with a cart clinking with open bottles of vodka, wine, and whiskey.

As the Yak descended toward the endless tan expanse of Kazakhstan, the view began to resemble a NASA animation of a Mars landing. We touched down on the same runway used by the Soviets to recover the Buran space shuttle and rolled to a small customs building. A dog wandered the taxiway aimlessly.

After a seemingly endless bus ride, we dined at Energia's processing facility. Then we were off to the Sputnik Hotel, built last year by the French company Starsem, which launches communications satellites aboard commercialized Soyuz rockets. The hotel was modern and comfortable, in contrast to the accommodations some of my fellow travelers had endured in Baikonur for Norman Thagard's launch five years ago. They told of water unsafe even to shower in.

Very early the next day we were hustled aboard buses to the rollout of Expedition One's Soyuz. Along the way was Baikonur's small museum, tucked behind two small cottages, once residences of Korolev and his favorite cosmonaut, Gagarin.

When I later took time to visit the museum, I met in its small office Valentina Bulgakova, a slight, poised woman

who pads around the museum's creaky floors like a Bolshoi dancer. No multimedia presentations here—just amazing artifacts in plain view and touchable. Bulgakova explained the significance of each item, her soft voice followed by an interpreter's less melodious translation.

As we walked through the museum's rooms, images of Korolev, the bellicose and brilliant force behind the creation of the Soviet space program, appeared often in paintings, photographs, and heroic Soviet monuments. Workers began arriving at Baikonur in 1955 to build Site 1 for testing his R-7 intercontinental ballistic missile. As the workmen poured the concrete launch pad, laid track to tie into railroad lines, and raised facilities for construction of the R-7 itself, Korolev and other Soviet designers were already considering the booster—part of a cold war buildup as Soviet Premier Nikita Khrushchev aggressively developed nuclear-tipped ICBMs—for space exploration. Just two years after construction at Baikonur began, Sputnik was launched atop an R-7.

Today in the Baikonur museum is the portable phonograph that Korolev played to bring a little reminder of home to the workers toiling in a barren and forbidding landscape. Like Baikonur, the old record player remains stubbornly workable. Bulgakova lifted the player's arm and carefully placed it on the turntable's spinning disk, and the voices of Russian folk singers echoed in the room.

Even as that music was first heard on the plains at the cosmodrome, Korolev and his engineers envisioned sending a man into space, a dream that would be fulfilled atop a Vostok booster only four years after the launch of Sputnik. That first space traveler—Yuri Gagarin—remains the single most deified figure in Russian space history, and his likeness is inescapable at Baikonur. The Expedition One crew, like the crews of every Russian mission since Gagarin's death in 1968, brought flowers to his grave in Red Square before launching on their space missions.

Baikonur's museum holds many objects related to Gagarin, including the ground control panel from his flight, his uniforms, and even soil from his landing site, preserved in a silver container. The objects, lovingly displayed, reminded me of Christian relics displayed in the cathedrals behind the Kremlin wall, including a nail purported to be from the cross.

But there was much space history made at Baikonur after Gagarin, and one item in particular provided a strong symbol of how firm a foundation Korolev built for his country's space program. A small room held a complete Soyuz capsule, its orange and white parachute bundled on the floor. It sat as a museum piece, a spacecraft developed in the mid-1960s as Korolev's last and most enduring design. The Expedition One crew rode an updated version of the same capsule to the space station.



A tree planted after Gagarin's flight (above, at left) is the thickest in a grove that gets a new addition after the return of each Baikonur space traveler.

Past and present meld at Baikonur. On our way to the Expedition One Soyuz rollout, along the cosmodrome's potholed roads, the tour buses rounded a corner near a nondescript cluster of curious, white half-moon shaped structures. I later learned they were sections of the Soviet N-1 rocket, developed in the mid-1960s as a challenge to the U.S. Saturn V. The massive N-1 first launched in February 1969, but never flew successfully—all four of its launches resulted in catastrophic explosions or in-flight breakups as the Soviets desperately tried to beat, or at least keep pace with, U.S. moon missions. In the United States, a Saturn V has had a museum built around it at Kennedy Space Center. But at Baikonur, pieces of N-1 rockets—priceless artifacts of the space race—sit torched in half and used as storage sheds or even gazebos.

Farther down the same road a Buran, a Soviet shuttle that was tested and orbited on a single unmanned spaceflight sits abandoned to the elements. Harsh treatment perhaps, but this one, which was used for aerodynamic testing, is arguably better off than a sister ship converted into a tourist attraction in Moscow's Gorky Park.

We finally reached the Soyuz processing facility, a reminder that Baikonur remains a working spaceport. Russian technicians, who had spent months attaching the capsule to the booster and testing its systems, emerged from the building. Moments later, the Soyuz, cradled on a railroad car and shroud-

ed in early-morning fog, rolled nozzles-first out of the processing building. The glossy dark green rocket sparkled in flashbulb fireworks. Russian soldiers and workers pointed, smiled, and photographed each other as it rolled slowly past in the background.

And then the Soyuz vanished into the morning mist. Our Energia tour guides yelled for us to scramble onto the buses, and the crowd of onlookers left in a dusty cloud as their cars bolted away. Why the hurry? It was baffling to anyone familiar with the Space Shuttle's agonizingly slow crawl to Launch Complex 39 at the Kennedy Space Center. In moments the press buses were speeding along the broken pavement leading to the launch pad about three miles away. As we wheeled to a stop, there it was: The Soyuz had beaten everyone to the site, and was already backed up to the launch pad. As we got off the buses, our handlers admonished "no smoking" as we filed past railroad cars full of kerosene fuel for the Soyuz.

Lieutenant General Valeri Grin stood before the rocket and answered questions through an interpreter. Grin plays the role of both dove and hawk. He is the chairman of the intergovernmental commission that oversees launches in support of space operations, earlier aboard Mir and now aboard the International Space Station. He's also deputy commander in chief of Russia's strategic rocket forces. His world has changed much since he first came to Baikonur in 1970.



Top: Despite the acres of dilapidated facilities, Baikonur—in the midst of a commercial launch boom—remains the busiest spaceport on the planet. Far from the cosmodrome's tracking stations, Kazakh natives ignore preparations for launch.



Something over 30 you can trust: A Soyuz takes the first crew to the ISS.

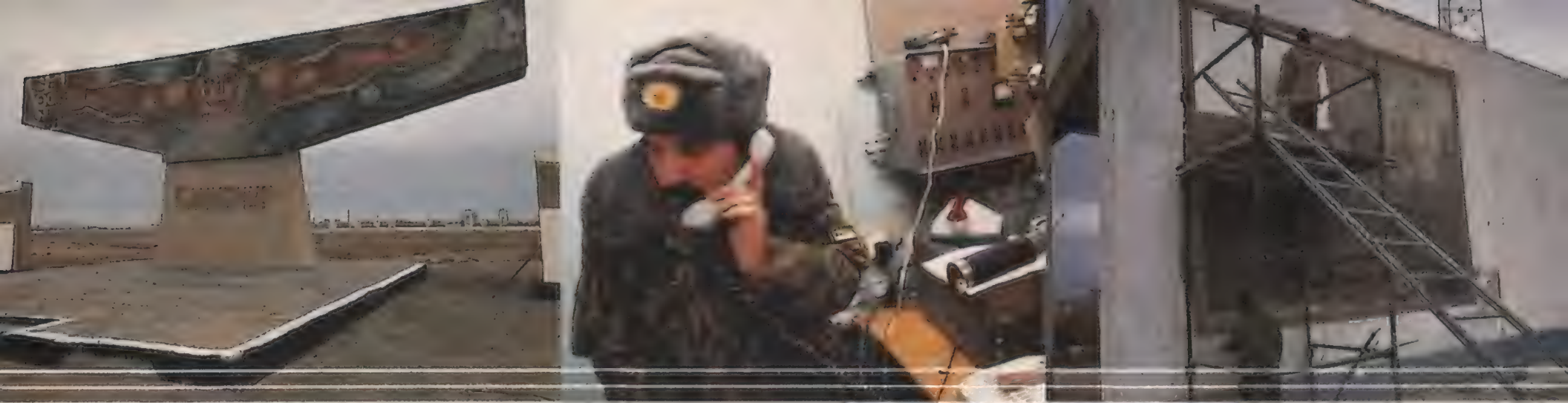
"The future of space is a global effort," Grin said. "We have a very good relationship working with the Americans." The International Space Station was topic A, but it was evident that Mir, which had been in space since 1986, commanded Grin's loyalty and pride. When he was asked by a German Public Radio reporter how he would bid farewell to the now deserted station, he dropped his head and seemed, for the first time, to search for words. "You have done well," he said finally. "You have served humanity. But now it is time for you to go."

At the edge of the concrete pad, crowded with onlookers and soldiers watching the Soyuz being readied for launch, a woman stood alone, clad in jeans, sneakers, and a ski jacket. She gradually drew a small crowd of reporters and well-wishers. The booster, topped with the cramped capsule that would carry her husband, Bill Shepherd, into space rose until it was finally vertical. Beth Stringham-Shepherd certainly had a personal stake in the upcoming launch, but it was also her professional role as a lead NASA strength trainer and rehabilitation coach that had brought her to Baikonur.

This was no Kennedy Space Center—not a palm tree in sight, and only an unchanging landscape of desert scrub all the way to the horizon. "I've never been to White Sands [Missile Range], but I hear this place is like that," Stringham-Shepherd said. "But I like the Russian traditions—taking flowers to [Yuri] Gagarin's grave, the reception for the families of the crew—we don't do any of that." And would her husband follow one other tradition, stopping at a roadside spot to urinate where Gagarin had done the same thing on the way to the launch pad?

"I guess he'll go with the flow," Stringham-Shepherd said.

SCOTT ANDREWS (2)



Left to right: At the entrance to the town of Baikonur, a cosmonaut's outflung arms welcome visitors; an engineer huddles in the blockhouse of Site 1, the launchpad of Sputnik and Yuri Gagarin; Site 1's blast wall gets new paint.

Launch day arrived in another foggy shroud. First we elbowed into the room where Shepherd, Krikalev, and Gidzenko were having their suits leak-tested behind a glass partition. Then it was time to jockey for a place outside, where we would all witness a tradition held over from the Soviet space program. For decades, cosmonauts had emerged from the building to prescribed marks on the asphalt, to stand at attention as the mission commander saluted smartly and reported to the senior general that the crew was ready for flight.

Only this time, an American stood on the commander's spot. Shepherd saluted, and Lieutenant General Grin softened the hard-edged Russian convention by stepping forward to clasp each man's hand and murmur final farewells.

The crew had been installed in the tiny Soyuz at least an hour before we arrived at the reviewing stands, which stood a half mile from Site 1. Concrete friezes of Gagarin, the Apollo-Soyuz spacecraft, and other cosmonauts and missions, their colors weathered into powdery pastels, decorated the outside of the buildings. The heavy fog persisted, but at 10 minutes before launch, the pad finally appeared in the distance, with the Soyuz frosted white from the frigid liquid oxygen within.

The sound hit first. A deepening roar, a flash as the rocket rose and cleared the tower, and then, just as on rollout day, it disappeared into the fog, reappearing 30 seconds later as a bright, diamond-shaped light high above our heads.

NASA Administrator Dan Goldin stood nearby sipping celebratory whiskey. "The Russians trust us to launch cosmonauts on the shuttle, and

we trust them to launch our astronauts on their rockets," Goldin said. "When we went to the moon, we were really proud—we knew we were changing history. But the ISS is a more significant activity... instead of pointing missiles at each other, we learned from each other. It's a wonderful day, not for America, not for Russia, but for the people who live on this planet."

Beth Stringham-Shepherd and astronaut Julie Payette had stood huddled around a television monitor sitting on the reviewing stand that showed a sometimes fuzzy view of the astronauts inside the capsule as it rose. There were cheers and hugs as Russian ground controllers announced via loudspeaker that the capsule had achieved orbit at the prescribed nine-minute mark.

Stringham-Shepherd held a cigar and glass of whiskey. Her cheeks were wet with tears. "Shep was beaming from ear-to-ear," she said. "It was great to see him so excited. I was kind of bummed I couldn't see the launch [because of fog] but maybe I can get back here for the next one."

The next Soyuz scheduled to fly to the ISS will deliver a docking compartment on a 2001 launch—five more space station launches are scheduled through 2006. But the cosmodrome's future lies not with the ISS, but in the booming telecommunications industry and its insatiable appetite for new satellites. Inside Energia's processing facility, where Soyuz capsules and unmanned Progress resupply ships are prepared for the orbiting space station, workers also prepare Proton upper stages for commercial launch.

"We completely redesigned this building," said Mikhail Malugin, who oversees Energia's Soyuz, Proton and Progress preparation in this building. "It

was used for the Buran program, but now we process Proton DM upper stages to deliver commercial satellites, and we are doing the final testing of Progress vehicles, including electrical and hydraulic systems."

Any talk of conducting commercial operations here would have been unthinkable when the complex was still a major center for military missile testing. In 1988 the Soviet government began removing from Baikonur ICBM launch testing facilities and their personnel. The process was made more urgent when Kazakhstan declared independence in 1991, and the cosmodrome suddenly ended up in a foreign country. The military still operates Baikonur's telemetry and tracking stations. Today, Russia relies mainly on Plesetsk—a military launch site in its own territory—for ballistic missile testing.

With the decision late last year to deorbit the Mir space station—the last Russian space program for the foreseeable future—Baikonur suffered another loss. But starting in the mid-1990s, increased investment began to point the way to a new future. The French company Starsem and the U.S. firm International Launch Services staked their claim at Baikonur with the construction of clean rooms for payload processing in 1999. Today, ILS, which launches satellites aboard the Proton—Russia's largest rocket—and Starsem, which offers an orbital boost aboard a commercialized Soyuz, are at the heart of a new era here.

In front of the cosmodrome's museum, the cottages of Korolev and Gagarin sit dark and abandoned, amid acres of crumbling buildings and burst steampipes heading off at drunken angles like pick-up-sticks. But no matter—the rockets still burn bright at Baikonur. —

Commen

Metric Mayhem | Michael Milstein

Practically the entire world uses the metric system. Is it time for the United States to follow suit?

Not long ago, I was writing a story for this very magazine about the delicate extraterrestrial dance of a U.S. spacecraft around a potato-shaped asteroid named Eros (see "Hang a Right at Jupiter," Dec. 2000/Jan. 2001). The simplicity of the spacecraft's course stood out in a universe that is rarely simple and convenient: The boxy craft would circle 100 kilometers from the asteroid's cratered surface, then fire its engines to drop into an orbit 50 kilometers above the tumbling space rock.

Finally, I thought, I don't have to worry about how to round off some impossibly large number such as the speed of light (299,792.458 kilometers per second) or the distance between Earth and the sun (149,597,870 kilometers).

At least that's what I thought until the editors got hold of the story and reminded me that this magazine does not use metric units. Convert all kilometers to miles, they said, all meters to feet, and all kilograms to pounds.

Why not use metric, I asked. All the scientists working on the spacecraft use metric. All their written materials use metric. Every other country that operates in space uses metric. Their reply: Because we have always done it the other way. It's what our readers understand. It's the American Way.

Lengthy investigation suggests that this is about the only explanation for why the United States as a whole evades the metric system while most of the rest of the world embraces it—because we have always done it the other way. We're like a crotchety old hermit. The rest of the international neighborhood works together and speaks the same

language while we huddle in a dark, outdated house at the end of the street (which we share with Liberia and Burma, the only other two nations that have not gone metric), mumbling our own inscrutable tongue of inches, feet, yards, miles, links, rods, furlongs, pecks, bushels, bolts, barrels, fathoms, leagues, acres, ounces, pounds, tons, cups, bales, pints, tablespoons, gallons, hands, chains—most of which have no logical relationship to one another—and all the other aged terms of what is often called the Imperial, or English, system but which metric advocates derisively refer to as FFU (Fred Flintstone Units). So I could have probably said

We're so used to
everyone else adapting to
our ways, we may have
forgotten how to adapt
ourselves.

to my editor, "That's typical FFU."

But of course I didn't.

Such lack of backbone may be why the U.S. portion of the International Space Station is built in Imperial Units while the rest of the super-expensive structure has been constructed in metric. About 10 years ago NASA gave serious thought to the idea of building the whole thing in metric, but decid-

ed that would drive the cost way up. All the NASA contractors were tooled to build parts in inches and pounds; converting to metric would have required revised designs and new machines. So instead they developed an elaborate and costly computer-modeling and cross-checking procedure to make sure that metric and Imperial parts fit together and work properly.

Of course, an all-out metric conversion would carry costs of its own. No one has ever solidly estimated it, just as no one has estimated the loss of U.S. trade dollars due to the unwillingness of other nations to take shipments in pounds and gallons. Certainly we would need to recalibrate scales, gas pumps, and the like. There's always a cost to repairing a sinking ship, but the cost of not repairing it may be far greater.

Right now the Russians are controlling the space station, figuring propulsion exclusively in metric units. Once the onboard laboratory (expected to have launched January 18) is up and running, the U.S. will take over control exclusively in Imperial units. When I asked spokesman Kyle Herring of NASA's Johnson Space Center in Texas what would happen if there were some confusion between the two, if a maneuver supposed to be carried out in pounds of thrust were actually done in kilograms or the other way around, he explained that the station's propulsion system operates at such low thrust that even a major miscalculation couldn't send it spiralling into the atmosphere. But it doesn't always take a major miscalculation to reveal the cost of our old-fashioned tendencies. Remember NASA's Mars Climate Orbiter? As it headed toward its rendezvous with the Red Planet in the summer of 1999, navigators calculated the effects of subtle maneuvers to adjust its trajectory, based on data from contractor Lockheed Martin. The data was supposed to be in metric units, but it wasn't, so

enary

each maneuver ended up throwing the craft farther out of whack, putting it more than 100 miles off course by the time it arrived at Mars. The \$125 million probe probably burned up in the Martian atmosphere.

The problem is that while Lockheed Martin's space division operates entirely in metric, its manufacturing side and many of its contractors use Imperial Units because rebuilding sophisticated hardware in metric would be wildly expensive, says Edward Euler, the company's program manager of the ill-fated Mars mission. For similar reasons, NASA requested proposals for its next generation of space shuttles in inches, feet, and pounds even while most of the agency's own scientists use metric. "You really have two NASAs—one English and one metric," says Euler, who adds that Lockheed Martin has the same problem. "We can't buy our nuts and bolts to the metric standard—that's the place, on the commercial and manufacturing side, where there's really resistance."

NASA and Lockheed Martin aren't the only ones suffering. About 20 years ago a Canadian airliner nearly ran out of fuel when U.S. ground crews filled its tanks with 22,300 pounds of gas rather than 22,300 kilograms. Corporate pilot Michael Payne says that when flying in Russia or China, air traffic controllers give altitude instructions in meters, leaving U.S. pilots to convert them into feet.

Among the first advocates for metrication in the United States was Thomas Jefferson, who as secretary of state asked Congress in 1790 to adopt a decimal system of weights and measures "and thus bring the calculations of the principal affairs of life within the arithmetic of every man who can multiply and divide plain numbers."

Congress waited 76 years before responding with the Metric Act of 1866, which legalized but did not require metrication. A century later, Congress passed the Metric Conversion Act of 1975 followed by a 1988 bill making metric the "preferred system of weights and measures" and beginning a voluntary conversion to metric, a forthright step everyone promptly forgot.

We're now left with a strange metric-Imperial amalgam that actually includes more metric measurements than you might guess: We buy soda in liters, we measure film in millimeters, and our track stars run 100 or 1,000 meters. Curiously, illicit drug dealers have gone mostly metric, and it clearly hasn't caused them any financial hardship.

But imagine cheering at the Indy 804.7 or reading 96561 *Kilometers Under the Sea*, says Matt Bartmann, who with his brother Dan created the website metricsucks.com as a joke to bring attention to their surplus-magnet business but then decided the metric system really does suck. There's no reason to upend our culture simply to conform to the rest of the world, they concluded. It's enough that liquor buyers already get ripped off by the metric system: For example, a "fifth" is actually 750 milliliters, slightly less than a true fifth of a gallon. "We never really liked it," Bartmann says. "Now we have good reason not to like it."

If it mixes up the nation's

top space engineers, though, how can we expect schoolchildren to grasp the outdated Imperial system? That's the question raised by Lorelle Young, president of the U.S. Metric Association, who cites studies showing that our students could save a semester's worth of school if they learned metric, where everything is based on multiples of 10. "I always like to compare it to when computers came in," she says. "People said, 'It's too hard to learn.' Now you couldn't imagine life without computers."

NASA, which was supposed to go all metric in 1996, adopted a new policy after the Mars Climate Orbiter "mishap" that requires "consideration of the metric system" for all new programs "unless such use can be demonstrated to be impractical or likely to cause significant inefficiencies or loss of markets to U.S. firms."

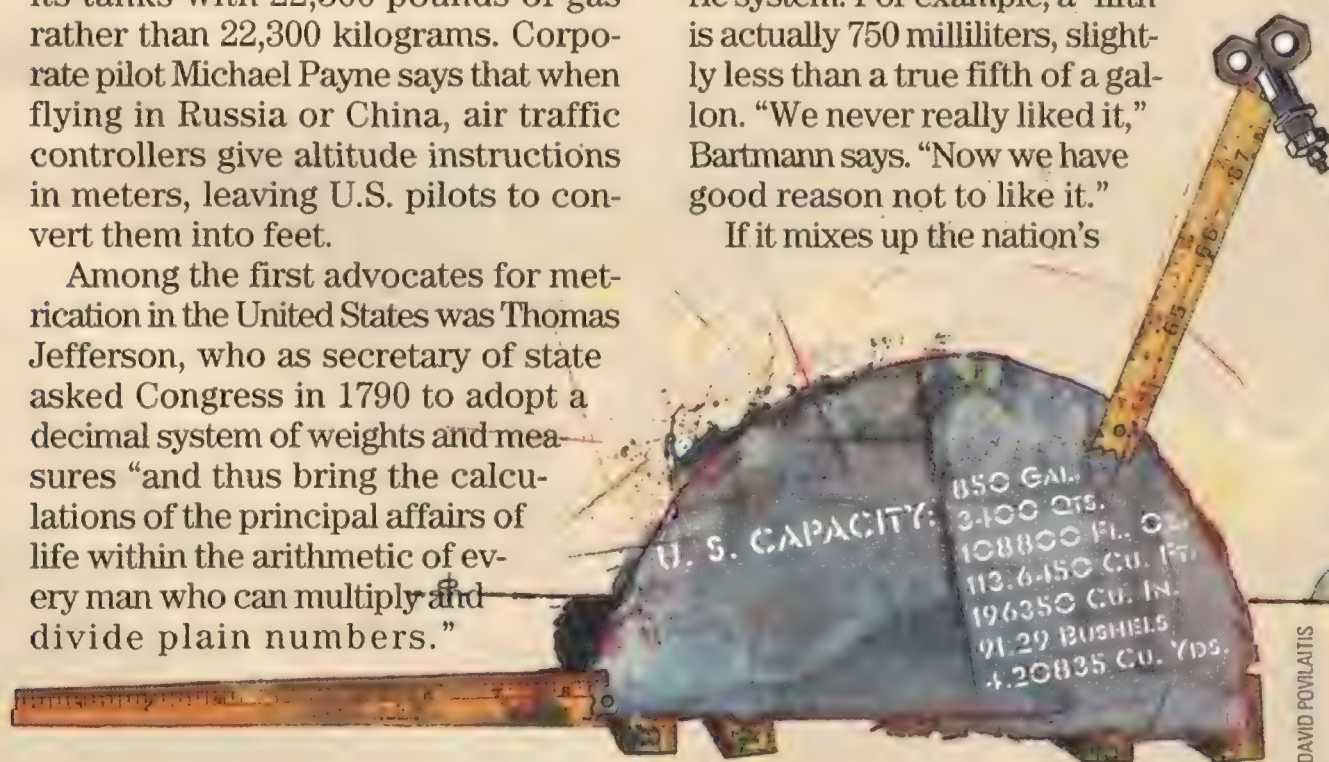
Backbone, anyone?

A few years back, the late Brian Welch, head of NASA's news operations, issued a directive saying the agency would use inches and pounds in news releases because that's what the public and the press understand. He was deluged with critical e-mail from metricationists. "I did not think it was our job to unilaterally drag the American public into the metric system," he recalled.

That may be, but doing nothing is almost always the easiest way to go. And as long as we can do nothing, we probably will. We're so used to everyone else adapting to our ways, we may simply have forgotten how to adapt ourselves. Oh, that spacecraft orbiting the asteroid? Listen up, editors: It circled 62.1 miles from the rock and then descended to a 31.05-mile orbit.

At least I think that's right...

Portland, Oregon-based Michael Milstein covers the environment and science for *The Oregonian*.





HIGH TENSION

AMES R. CHILES HELICOPTER PILOTS PLAY CHICKEN WITH HIGH-VOLTAGE POWER LINES SO CREWS CAN WORK ON LIVE WIRES.

PHOTOGRAPHS BY JEFFREY BROWN/AURORA

To some people, it would be cause for much grief, this Hughes MD 500 helicopter sitting in the hangar, rotor blades snapped, tail boom sheared off, Plexiglas cockpit nose broken. Repairs will cost at least \$160,000.

But to Darryl Ed, president of Haverfield Corporation of Gettysburg, Pennsylvania, a helicopter company that maintains power lines, it's nothing to mope about. He says the fact that the two men on board walked away largely unscathed was due to world-class piloting—under the circumstances.

The circumstances were this: Pilot Dennis Anderson's job that day last

Dennis Anderson holds a tight formation with a 465,000-volt transmission line while Jeff Pigott splices in new cable.

April was to hover the MD 500 a few inches from a live 230,000-volt power line west of Chicago so that an electrician sitting on a platform on the side of the helicopter could work on the line from the air. The helicopter's rotor blades overlapped the power line. The Allison turbine engine quit suddenly, leaving the rotors spinning only from inertia. In the second or two before the Hughes settled enough to put the rotors into the power line, the lineman disconnected his equipment from the line. At the same moment, Anderson banked the aircraft sideways. It whirled toward the ground a hundred feet below, gathering speed.

When an engine quits, helicopter pilots wish for a surfeit of altitude or speed. In an unpowered descent—called an autorotation—either will allow the free-spinning rotor to build up enough rpms for the pilot to soften the landing by pulling up the collective



Deposited on transmission lines in the Everglades, Haverfield workers James Reisz (left) and Mark Youngblood make quick work of changing a rubber spacer. Helicopters make such user-unfriendly sites easily accessible.

lever at the last moment. This causes the rotor blades to dig into the air and slow the descent. But when an engine quits at 100 feet, the options are few.

Anderson aimed toward a patch of swamp, the softest spot in the immediate area. The MD 500 hit the ground so hard the rotor blades bowed downward and chopped off the tail boom. The front of the skids sank into the mush, leaving the helicopter in a showy headstand. It was a fortunate anticlimax. Anderson had missed the power line and even saved the helicopter fuselage. It was not a routine day, but little is routine in the live-line bare-hand maintenance business.

The U.S. power grid has nearly 160,000 miles of high-tension transmission lines, each line carrying 230,000 volts or more. Sooner or later such lines need attention, which might entail changing out hardware hanging on the lines, stringing fiber optic cable, or excising short sections of worn wire and splicing in new.

Big transmission lines usually have three "conductors" consisting of two or more closely spaced wires. The conductors run parallel, separated by 20

feet or so, and hang from bell-shaped ceramic insulators, which are suspended from the arms of steel towers. Previously, linemen climbed up the towers and clambered along the conductors, but this required the power company to shut the power off first. Today, power companies prefer not to shut down transmission lines for routine maintenance, because closing down a 500,000-volt line, for example, can run as high as \$50,000 per megawatt hour in replacement power costs.

That's where helicopters come in, flitting from span to span like big hummingbirds—a sight that often prompts onlookers to call police and report that helicopters are stuck in the power lines. A lineman can perform many operations from a helicopter—while the juice is on. Today, hundreds of crews worldwide are doing "helicopter live-line bare-hand maintenance." In this country, the work is done by a handful of contractors and by utility companies.

It sounds insane, especially to pilots, who are taught to steer well clear of power lines. Live-line maintenance was featured on the History Channel's "Suicide Missions" series last year. "TV

shows portray this as seriously dangerous work, like lion taming, but that is not at all the case," says Bob Feerst, president of Utilities/Aviation Specialists, a company that trains crews and audits flight operations for safety. "It's very safe if the crews follow procedures and the people are trained." Done right, Feerst says, it's no more dangerous than working from the bucket trucks that raise linemen to the wires.

Which is not to say that it offers room for mistakes. In the last six years, helicopter live-line maintenance accidents have claimed three lives. "If you factor out deep space and covert military action under enemy fire," Feerst says, "operating in the utility wire environment is the most demanding flying, by far, and needs the most skill from the pilot and crewman."

In 1979, Michael Kurtgis was transporting Florida Power and Light employees as the company's chief helicopter pilot. He considered the time that conventional crews spent setting up and breaking down for even simple power line tasks, and figured that a he-

licopter could speed things up immensely. He approached his managers and two helicopter manufacturers with the idea of working on live transmission lines from a helicopter and proposed some trial runs, since no one had ever tried flying so close to wires—not on purpose, that is. “They thought I was out to lunch,” he says. Kurtgis resigned to start his own power line maintenance contracting company, USA Airmobile in Fort Lauderdale, and patented his methods, but couldn’t prove his idea would work because no power company would allow him to connect his helicopter to an energized power line—that is, establish an electrical connection between the conductive helicopter frame and power line, equalizing the electrical potential so that whatever—or whoever—touches the line won’t get shocked.

Nearly two years went by before Kurtgis got his chance. In early 1981, USA Airmobile won a contract to power-wash insulators on a 115,000-volt

line in Dammam, Saudi Arabia. One day during the job, Kurtgis, ready to start work in a Bell 206 JetRanger, had an impulse: He called over the intercom to crewman Jim True, “It’s now or never.” Out here, there was no one to put up roadblocks. “We’ll never get this kind of chance again,” Kurtgis said.

True asked Kurtgis whether he was really sure this would work. Kurtgis said he was pretty sure.

Nobody in a helicopter had physically connected with a live, high-voltage conductor, and the people that Kurtgis had talked to weren’t sure what would happen. A short circuit from high-tension lines to the ground, perhaps through a fallen tree, is enough to blow the tree apart. Would connecting the line to a helicopter stun the crew, or ignite fumes in the fuel tank? A Florida Power manager predicted that a voltage surge would short out the helicopter’s electrical bus.

Airmobile crews had already worked close enough to energized lines to learn that protective clothing is a must. Kurt-

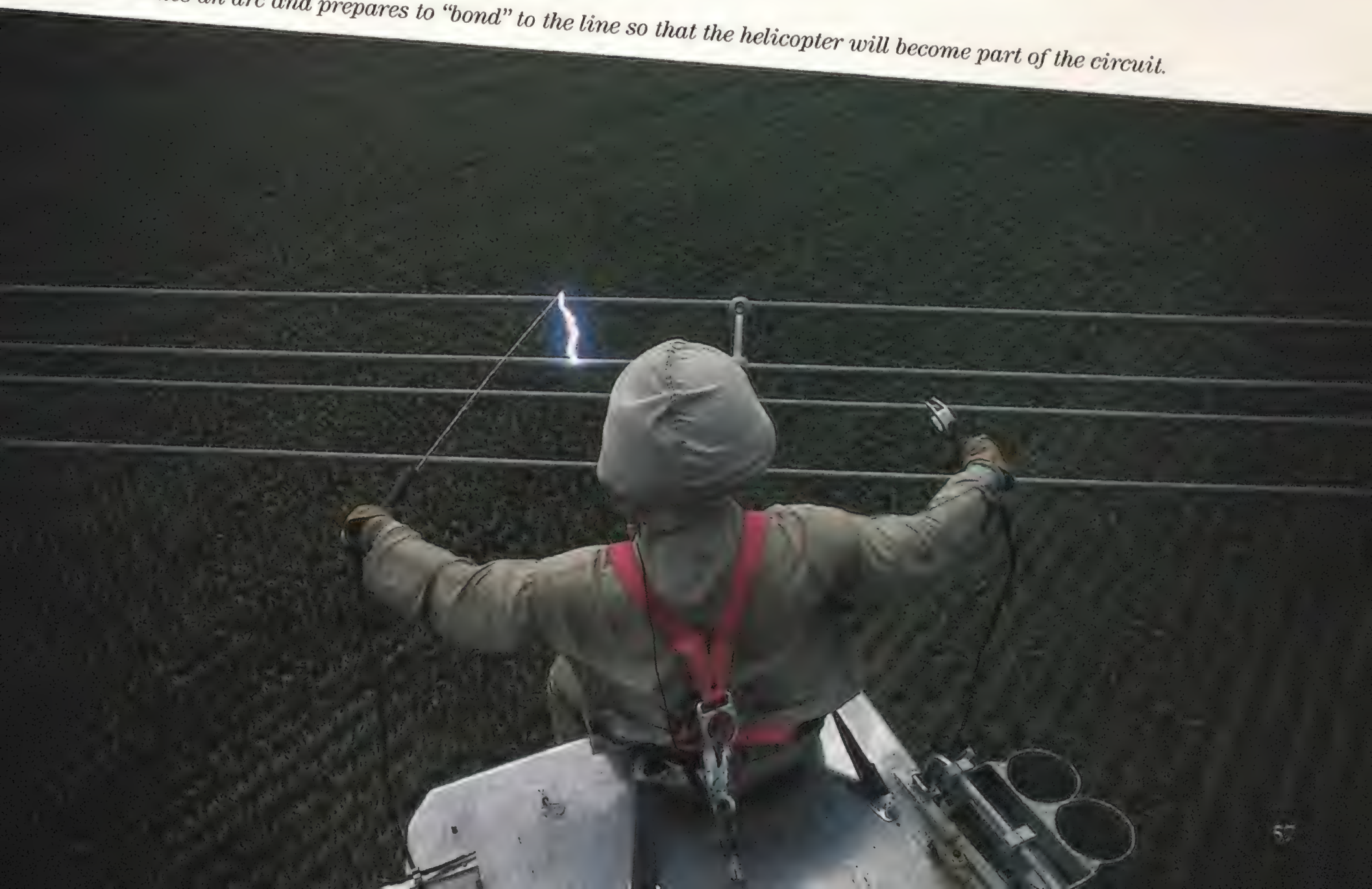
USA AIRMOBILE



A USA Airmobile crew power-washes insulators, blasting off dirt that can cause a short circuit to the steel tower.

gis had a close encounter with a 500,000-volt line before he had even tried to touch any energized lines from a helicopter. “It was like a whole bunch of fire ants were biting you,” he recalled. What had bitten him was “induced current.” High-voltage power lines create a very strong electromagnetic field that reaches far beyond the three conductor wires. This field is not so much a byproduct of the current as a carrier of the current itself. Anyone in the immediate vicinity, like the pilot in a hovering helicopter, is in this field and will feel an induced current along his skin regardless of whether he touches the power line. The sensation is itchy at lower voltages and distinctly painful

Reisz strikes an arc and prepares to “bond” to the line so that the helicopter will become part of the circuit.



at higher voltages. Kurtgis learned that a suit of conductive clothing—Nomex fabric with a weave of 25 percent fine-mesh stainless steel wire—allows the current to flow around the skin.

When Kurtgis sidled the JetRanger close enough, True swung the conductive metal boom of the power washer over to the 115,000-volt power line, causing an arc and the attendant buzzing noise as the arc hit the boom. The arc jumps because the helicopter has a different electrical potential than the power line, and the voltage wants to jump across the air gap to equalize them. Even though he expected an arc, True yelped in surprise, but they were still in the air. Once that connection was made, it was easy to “bond” to the line—attach a cable from the helicopter frame to the line to maintain a good electrical connection between the two. Using such techniques, crews have connected the frames of their helicopters to power lines carrying a million volts.

I met up with Kurtgis last August at a power line training facility operated by American Electric Power near South Bend, Indiana. Performing for a small group of electric-utility maintenance managers, Kurtgis’ crew took a

Pilot Jed Gerbrecht and Reisz huddle before flying a mission. In the potentially lethal environment of live-line maintenance, pilot and lineman must function as a unit.



Bell 206 JetRanger through its paces: power-washing insulators to blast off dirt that can cause a short circuit to the tower, hanging a big orange plastic ball on the topmost wires to warn off aircraft, and bolting on spacer brackets that keep parallel wires from chafing each other in the wind.

Much live-line maintenance work involves a lineman sitting on an aluminum platform suspended from the helicopter frame. From this perch, sitting just below the pilot, the lineman has a better reach and posture than he would achieve by leaning out the helicopter door (and the pilot can easily keep him in close sight). It also provides a secure mounting for his generator or air compressor for power tools. Under federal aviation regulations, such an external load puts a helicopter in a restricted category. A crew must be able to jettison the platform in an emergency and therefore cannot hover over occupied buildings or congested areas while carrying it. A lineman working from a platform connects his safety harness to the helicopter rather than to the platform.

In some cases the lineman hangs 50 feet or more below the helicopter at the end of a string of “hot sticks,” rigid fiberglass rods. Since fiberglass does not conduct electricity, the pilot can drop off the lineman at places that the helicopter could not safely approach.

Airmobile’s chief pilot, Doug Lane, flew helicopter gunships for a year in Vietnam and was shot down twice; on the way to Airmobile he flew freight, did traffic reporting, and shuttled oil-field workers to platforms in the Gulf of Mexico. According to Lane, on top of learning new regulations, power line technology, and his company’s specific procedures, an incoming pilot needs to break through a mental barrier to be willing to bring the lineman close enough to the wire—about eight inches from his chest. “When he first comes in,” Lane says, “he’s saying to himself, ‘I don’t want to hurt this guy,’ meaning the lineman, so he’s keeping his distance from the lines. But everything the lineman does is from the upper body, because he’s sitting on the platform.” At times linemen work with pulleys, clamps, and tools that are too heavy to reach out very far with. “The pilot can work [a lineman] to death in





two hours if he stays too far away," Lane said. "He wants the work right in his face."

A crucial part of a new pilot's training is to ride with a crew, watching how an experienced pilot helps the lineman and vice versa. That's why Markus Schiess donned his international-orange flight coveralls one August day and joined a Haverfield crew and its MD 500 helicopter in a meadow in the Appalachian Mountains of central Pennsylvania. Schiess' logbook shows over 5,000 hours hauling logs in Alaska, running low along rivers in Africa to spray pesticide, instructing in light helicopters, and transporting executives in Taiwan. Schiess fit well the power-line personality profile that Darryl Ed, head of Haverfield, had described: meticulous, confident, with a good sense of humor and an enjoyment of life. Daredevils, Ed had said, need not apply.

In less than a month, Schiess would be doing power line work in Chile for Haverfield, and this week was an opportunity to pick up pointers from pilot Mark Campolong and his crew, foreman Ken Black, lineman Jeff Pigott, and data man Craig McCleaf, who tracks work accomplished and notes any power line damage not visible from the ground. Joining them was Al Knerr, a crew chief from Pennsylvania Power and Light, the owners of the line.

At 10 a.m., before operations started, Black called a quick safety meeting. Though his crew had been working on the 34-mile Montour, Columbia, and Frackville transmission line all summer, taking old hardware off and bolting on new equipment, Black went over the basics again. The three conductors carried a total 230,000 volts; they were spaced far enough apart that the helicopter could hover alongside the center conductor. At Haverfield's request, Pennsylvania Power and Light had set the line to "manual reclosure" so that if anything got shocked it would

Once bonded to the line and "wearing" 465,000 volts, the crew is protected from the uncomfortable effects of induced current by a conductive suit of Nomex and fine-mesh stainless steel wire.

be only once rather than the three times that would occur as automatic reclosers tried to restore service to the line.

Black pulled out a dog-eared wallet card listing the minimum distances the helicopter needs to keep in this particular voltage situation—eight feet from a conductor when between wires, five feet from a conductor when between a wire and trees—to prevent a short circuit from passing through the helicopter. “Whatever distance it says, we double it,” Campolong added for Schiess’ benefit.

As the crew loaded hardware onto the work platform, Campolong started the MD 500. In two quick flights, he deposited Black and Pigott where the lines crossed a hundred feet above a dairy farm. As Campolong flew off, each man attached his safety harness to a conductor and scuttled spider-like toward a tower. Later, at Campolong’s signal, Schiess donned a set of beige conductive clothing and climbed into the rear seat to watch him work.

The weather was good for power line work: high clouds and only a 5-mph breeze. Campolong offered advice as various situations arose. He suggested that when dropping off linemen on the wires, Schiess get as close as practical to the towers; the further out, the more the lines jump around when a lineman gets on or off. Because placing men on wires near towers is exacting work, Campolong told Schiess he usually did that kind of thing in the morning before the air got hot and winds picked up. Afternoons were good for working out in the center of the spans between the towers. Schiess should beware of a steep hillside, where the wires’ slope would put the rotors at risk.

Crews can operate under a wide range of visual flight conditions. When working from a platform, they can tolerate light rain and even a 25-mph wind if it is steady. Variable winds are acceptable if the “gust spread”—the difference between highest and lowest

speeds, is under 10 mph or so. A higher spread can shift the helicopter faster than the pilot can correct. For hanging a lineman on hot sticks that drop through a set of wires, the requirements are stricter: no rain, not even a dew-point that might cause condensation that would allow voltage to jump from one conductor to another via the moisture. For that reason, crews wipe the hot sticks clean each morning.

After lunch the crew went aloft to begin replacing old spacers on the wires. I borrowed a conductive suit and gloves from Schiess and climbed in the back. The helicopter rose briskly and headed for a span of power line to the south. Campolong matched altitude with the wire and approached it with seasoned confidence. Pigott took a three-foot metal wand connected to the helicopter and stretched it out to the wire, striking a foot-long arc. Holding the rod against the wire with one hand, he used the other hand to bond us to the wire by clamping a cable to

Jerry Kirby deplanes 150 feet above the Everglades. Live-line maintenance was featured on the TV show “Suicide Missions,” but company officials say it’s as safe as working out of bucket trucks that raise linemen to the wire.





A pilot must get a lineman within inches of a line. Onlookers sometimes report a helicopter “stuck” in the wires.

it. We were now a part of the circuit, in effect “wearing” the full voltage of the transmission line. From here we could admire the trees, but if we were to contact a branch we’d instantly be electrocuted when the voltage passed through the helicopter to the ground. “You’ve got 230,000 volts flowing around you now,” Campolong said.

Campolong stabilized the helicopter to put the conductor about level with Pigott’s midsection and over his legs. Campolong kept his gaze over his shoulder in Pigott’s direction, sparing only quick glances at his instrument panel and the sky. He made it look easy, but holding a helicopter in midair with only a few inches’ margin of error takes intense concentration. Just a few minutes will exhaust a neophyte.

Whatever the wind direction, the pilot has limited choices about how he approaches the wire. Because visibility is so crucial, he must have the wire on his side, stay clear of other wires, and keep the skids parallel to the wire in order to keep the tail rotor away from it.

Brian Parker of Haverfield, a longtime power line pilot, compares the

difficulty to riding a unicycle on a moving walkway while someone flicks the walkway power on and off. Campolong told me, “My mother-in-law asked me once, ‘Why are you so tired? You just sit around at work all day.’”

In less than half a minute, Pigott, sitting comfortably on his platform, pried off two metal spacers installed 30 years ago when the line was built, slung them under the fuselage, and disconnected the helicopter from the wire. Campolong backed away, moved a hundred feet southeast, and came back to the wire so Pigott could bolt on a new aluminum spacer bracket in a new location. In 10 minutes this part of the span was done and Campolong headed back to the landing zone for more hardware. “Piece of cake,” he said over the intercom.

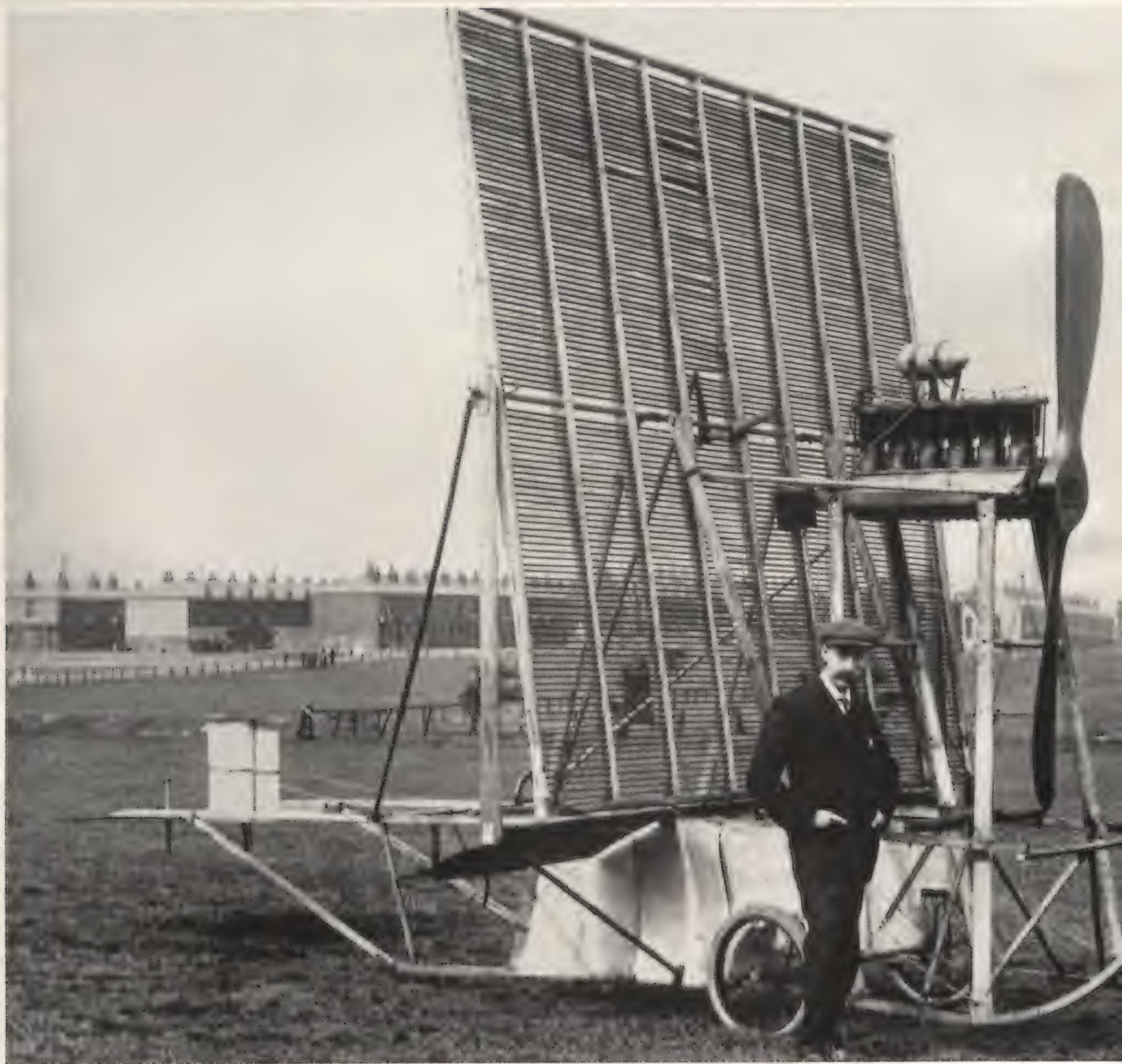
Before I left, Campolong handed me a poem he wrote. It ended: “Next time you turn on the switches without a

Mission accomplished, a Haverfield crew unloads. Despite the image live-line work evokes, “daredevils need not apply,” says Haverfield president Darryl Ed.

thought/Remember the guys who are repairing it ‘hot.’” And, he could have added, if you happen to see a platform-equipped helicopter hovering inches from a power line, don’t bother calling the cops. —



Were They Thinking?



BY PHIL SCOTT | The wonderful, unworkable world of
airplane design in the years before the Wright brothers.

Horatio Phillips endowed his turn-of-the-century craft with hundreds of slats, or "planes," presumably to produce as much lift as possible.



What the Wright brothers accomplished in four years, other would-be aeronauts had been attempting for decades. The brothers distinguished themselves by realizing that what a flying machine needed was a pilot with complete control over the machine, and a machine that would allow itself to be completely controlled. Their wing-warping biplane, the *Flyer*, was the first powered airplane that enabled the pilot to control the craft's pitch, roll, and yaw—its movements along the three axes of rotation: lateral, longitudinal, and vertical.

The brothers' aeronautical contemporaries, however, did not have the benefit of this wisdom. Because the Wrights wanted to protect their invention by securing patents for it around the world, they initially kept their mastery of powered flight a secret. That left other designers of the day to proceed from intuition, guesses, aesthetic judgments, trust in engine power—everything but the theory of three-axis control.

The Wrights made their first official public demonstration of powered flight in 1908, at an Army Signal Corps field in Virginia. Most competing aircraft designs quickly faded into the background.

Now, a century later, they are en-

joying a revival of sorts. These rarely seen photographs of early aviation's also-rans hail from the archives of London's Hulton Getty Picture Collection. "They had a big collection of aviation pictures sitting in a back room, covered with dust," says Peter Almond. "Someone said, 'Gee, look at all these pictures—let's put a book together.'" The result: *The Hulton Getty Picture Collection—Aviation: The Early Years*, with text by Almond (Könemann, 1997). The book has the feeling of a family photo album—only with pictures of all the relatives no one talks about.

The World's First Lifting Body

In 1884 and again in 1891, British inventor Horatio Phillips tested a variety of wing sections in an early wind tunnel, in which he used steam to study the movement of air along various surfaces. "The particles of air struck by the convex upper surface...are deflected upward...thereby causing a partial vacuum over the greater portion of the upper surface," he wrote. And thus Phillips happened on to the principle behind every successful wing: Air flowing over a curved top surface moves faster—and thus has lower pressure—than air flowing against a wing's flat bottom. It's this difference in pressures that produces lift. Had he left it at that, Phillips would have been remembered

Modelled on a sea bird, Jean-Marie Le Bris' glider had an early form of pitch control in its wings.



HULTON GETTY/IAISON AGENCY (2)



HULTON GETTY/LIAISON AGENCY (2)

It looked like a cross between an umbrella and an old-fashioned hooded camera, but Clement Ader's Avion III was actually inspired by the bat.

as having made a great contribution to aeronautical science. But he insisted on trying to build a flying machine.

In 1893 he designed a craft with 50 slats (hence the name "multiplane"). Presumably, he was hoping all those planes would produce lift in abundance. The frame measured 22 feet long and only 1.5 inches wide; the machine was powered by a coal-fired engine that turned the propeller at 400 revolutions per minute. The whole thing looked like a flying Venetian blind.

In 1892, Phillips managed to get the multiplane aloft for part of a lap over a circular track. That wasn't enough to impress fellow aeronaut and designer Octave Chanute, who wrote in his 1894 classic *Progress in Flying Machines*: "Mr. Phillips's experimental machine neglects any provisions for maintaining equilibrium in full flight, or for arising and alighting safely."

A 1907 design, which bore four frames with 200 tiny planes, flew some 500 feet; no word on how the version shown

here, a 1911 single-frame machine, performed. Probably not impressively; the Venetian-blind airfoil is not one that designers have returned to often in the years since.

The Mechanical Albatross

French sea captain Jean-Marie Le Bris marveled at the sight of albatrosses effortlessly flitting about above his ship, so he killed one. He wrote later: "I took the wing of the albatross and exposed it to the breeze; and lo! in spite of me it drew forward into the wind; notwithstanding my resistance it tended to rise. Thus I had discovered the secret of the bird!" Upon returning to France, Le Bris constructed what was essentially an albatross big enough to hold a man. It was just over 13 feet long and had a 50-foot wing. There was no undercarriage, just a canoe-shaped wood hull where Le Bris intended to stand while piloting the glider. "An ingenious arrangement...worked by two powerful levers, imparted a rotary motion to

the front edge of the wings, and also permitted their adjustments to various angles of incidence with the wind," wrote Octave Chanute. These controls apparently were to have provided pitch control. Le Bris also designed a hinged tail for steering, both vertically and horizontally.

Le Bris first attempted a flight in 1857. He tied the albatross to a horse-drawn cart; when the driver urged the horse into a gallop, LeBris untied the knot and the albatross leapt skyward, lifted by its wings. Unfortunately, the rope wound around the cart's driver and pulled him into the air. Le Bris managed to gently lower the driver to the ground unhurt, but he also crumpled a wing. On his next attempt, which he made from the edge of a precipice, "the apparatus...oscillated upward, and then took a second downward dip" and fell to the bottom of the pit, reported Chanute. In the crash, Le Bris broke a leg, and his glider was destroyed.

In 1867 he built another, much like

the first, though a bit lighter and with a counterweight inside that was supposed to move automatically to provide equilibrium; if the craft pitched downward, for instance, the counterweight would move backward to compensate. On the glider's one piloted flight Le Bris flew perhaps 75 feet; on its final flight, the glider rose from a hill, then dove toward the ground, smashing to bits.

"Le Bris had made a very earnest, and, upon the whole, a fairly intelligent effort to compass sailing flight by imitating birds," Chanute wrote, but the designer failed to solve the problem of maintaining longitudinal equilibrium. In addition, says Peter Jakab, a curator of early flight at the National Air and Space Museum, "There wasn't any calculation of lift and drag and those sorts of things."

The Adventures of Batman

Clement Ader's aircraft owed their shape to the bat. And because bats don't need tails, Ader found very little use for one either. But he must have believed storage was important, because his first, the *Eole*, could fan-fold its graceful 54-foot wing.

The craft was supposed to make its maiden flight in 1890 over the seclud-

ed Parc d'Armainvillers grounds in France, powered by a 20-horsepower steam engine. "An area was laid out in a straight line unturfed, beaten and leveled with a roller," Ader wrote six years later, "so that one could see and record the traces of the wheels from the slightest lift to complete takeoff." The ride was wild: 164 feet from start to finish, and just inches above the ground.

Ader convinced the French War Ministry that he could build a bigger and better flying machine; nearly six years later, the *Avion III* (shown here) debuted. It was powered by two steam engines (the *Eole*'s single powerplant had created destabilizing torque), and it had a wingspan of 60 feet. Much like a bat, it was all wing and no tail. Ader sat behind the engines without a clear view of what lay ahead, though he did have some control over the wings: Hand cranks could change their angle of incidence—albeit too slowly to do much good.

Did the *Avion III* actually fly? Ader claims it did, but some historians doubt it. Here's the story according to the book *The Road to Kitty Hawk* by Valerie Moolman: In 1897, with two generals observing at the circular track at Camp Satory near Versailles, Ader climbed into the machine, started its

engines, and took off, with the wind blowing from behind. The machine was suddenly airborne, and Ader, fighting to stay inside the track's perimeter, steered to the left. But the wind blew him to the right. Ader cut the power and landed hard. It's not clear whether the machine had been propelled by its engines or by the wind. In any case, it was so damaged that further tests were postponed indefinitely, and the War Ministry halted funding.

Years later, Wilbur Wright hailed Ader as a pioneer of flight, but in 1910 he wrote a letter to the editor of *Aircraft* magazine clarifying his position. "[T]he Ader machine had...quite failed to solve the problem of equilibrium," he noted. And, of course, the pilot had made the grievous error of trying to take off downwind.

Flexible Flier

In 1894, Sir Hiram Maxim, an American inventor living in Britain who gave us the machine gun, a telegraph, several systems of lighting, and more than 260 other inventions, put the finishing touches on an aerial brainstorm, which he called the "kite of war." It was a huge biplane: some 4,000 square feet of wing surface area and weighing an astounding 8,000 pounds. Maxim gave it two engines, one on the right side and the other on the left, because he had a theory about flight control. He believed he could steer his machine to the right or the left "by running one of the propellers faster than the other." The difference in power was supposed to yaw the craft.

On July 31, Maxim prepared to test his great kite. He had constructed a track with an iron rail on which the machine's four wheels would sit. The vehicle was to take off down the track like a winged sled; as it gained speed, its crew would attempt to raise it off the rail by use of its "fore and aft horizontal rudders." The track also had a wood guardrail that was to keep the craft from climbing too high.

With three crewmen onboard, the machine lurched upward. And then it kept going, until it had snapped right through the upper guardrail. Maxim cut power and the kite settled down, one of its propellers cracked from hitting the wood railing. The flight had

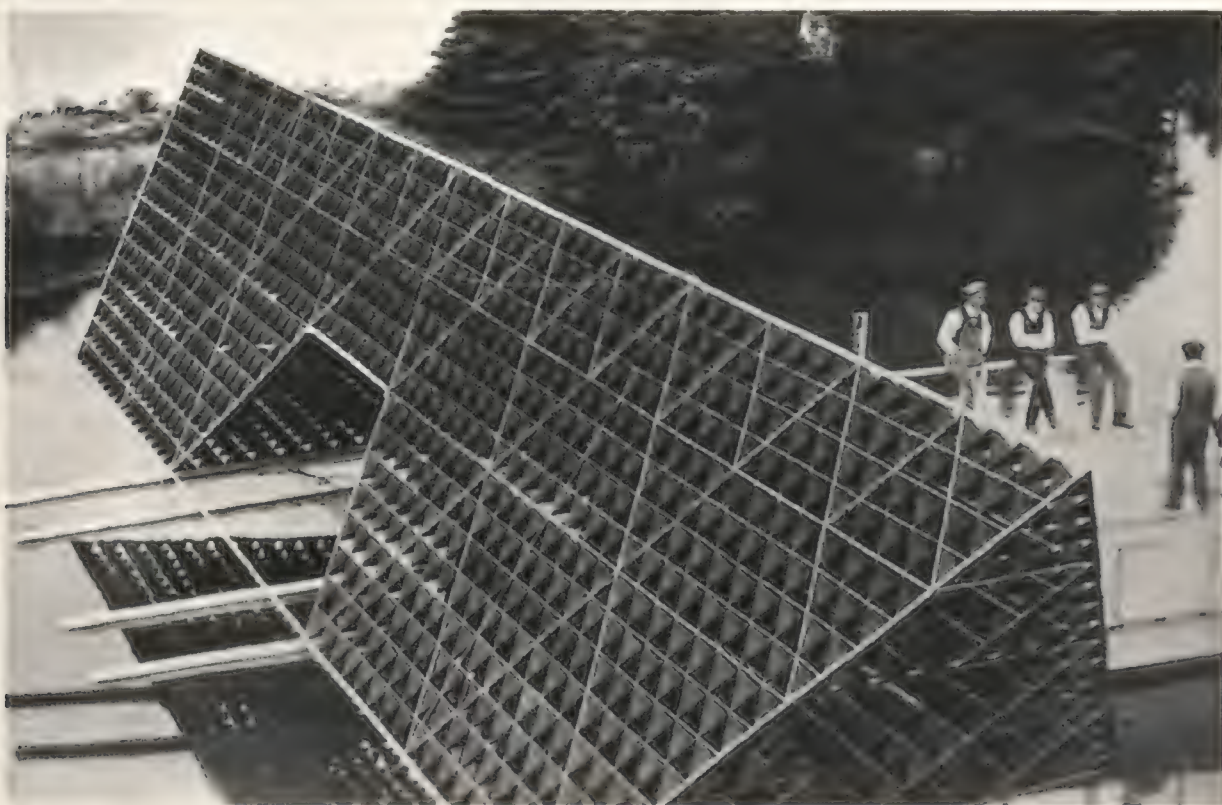
In addition to designing the monstrous "kite of war," Hiram Maxim came up with a technique for controlling yaw.





HULTON GETTY/LIAISON AGENCY (2)

The 14 bis, Alberto Santos-Dumont's backward-looking machine, made a public flight in Europe before the Wright Flyer did.



NASM

Alexander Graham Bell was infatuated with the tetrahedral, or four-sided, cell, but only one of his tetrahedral kites flew.

ended before Maxim had been able to test his theory about steering.

"Maxim spent 30,000 pounds, and his contribution to aviation was virtually nil," says Peter Almond, who nonetheless decided to include Maxim's machine in the Hulton Getty book: "I took a slightly generous view of him because of the sheer chronology," he explains. "He did this in 1894, before anyone else had done any of it."

A Strange Duck

Alberto Santos-Dumont, son of a wealthy Brazilian, used his money to experiment with flying machines. Following the lead of Gabriel Voisin, who in July 1905 managed to get himself towed aloft in a glider dragged behind a rac-

ing boat, Santos-Dumont envisioned one of his dirigibles, No. 14, dragging an airplane, 14 bis ("bis" being French for "II," or "the second"), into the air. He had mechanics build a light frame of pine and bamboo, with wings that swept upward—behind the operator, who stood in the cockpit facing the boxy elevator. An Antoinette engine turned the four-blade aluminum pusher propeller behind the pilot.

Though Santos-Dumont thought the craft resembled a bird of prey, most observers thought the elevator looked like a duck's head sticking out in flight, and called the machine *canard*, French for "duck."

In September 1906, Santos-Dumont, now using an engine powerful enough

to obviate the need for a dirigible launch, managed to hop 23 to 43 feet (different observers gave different estimates). The following month, before a crowd that included members of the Fédération Aéronautique Internationale, formed the year before to keep aviation records, Santos-Dumont stood at the controls, advanced the throttle, and lifted off, flying 197 feet before touching ground again. It was the first official, public flight of an airplane in Europe.

The Wrights acted unimpressed. "If he had gone more than 300 ft. he has really done something; less than this is nothing," Wilbur wrote to Octave Chanute.

Though Santos-Dumont devised an elevator similar to the Wrights', in general, the designer "didn't develop [14 bis] in the same way that the Wrights developed theirs, based upon lift and drag," notes curator Peter Jakab. "That's the thing that separates the Wrights. The *Flyer* was truly an engineered aircraft."

Santos-Dumont was back in the air in 1909 at the Reims Meet in France with his *Demoiselle*, a more Wright-like monoplane that flew but set no records. Suffering from multiple sclerosis, he committed suicide in 1932 at the age of 59.

The Angular Swan

Alexander Graham Bell grew interested in flying machines while watching his friend Samuel Langley experiment with his Aerodromes in the last decade of the 19th century. In 1907 Bell formed the Aerial Experiment Association with a handful of young men, including Glenn Curtiss, with the intent of getting into the air as soon as possible.

Bell was a big believer in the four-sided triangular cell—the tetrahedron. Such a cell possesses, he wrote, "qualities of strength and lightness in an extraordinary degree. It is not simply braced in two directions in space like a triangle, but in three directions like a solid...." Using hundreds of fabric tetrahedrons, he constructed huge craft he called Cygnets, or Swans.

In 1907, AEA member Lieutenant Thomas Selfridge flew the first one from Bras d'Or Lake near Bell's summer home in Nova Scotia. It was towed behind a steamer. It had no controls,

and after it landed was dragged apart. Bell completed his *Cygnét II* within two years; this one had a triangular “wing,” weighed some 900 pounds, and rested on runners; the pilot sat behind the biplane elevator and in front of a pusher engine with a 10-foot propeller.

Despite three tries that February, the *Cygnét II* remained firmly adhered to terra firma. What kept it there? “Drag,” says Tom Crouch, an early-aviation curator at the National Air and Space Museum. “What works for a kite doesn’t work for an airplane.”

Been Too Long at the Fair

The Marquis d’Ecquevilly was a French naval engineer who got into the aviation field in 1907 with his strange and beautiful multiplane, about which little has been written. He started with a four-wheel platform on which the pilot stood, upon which he mounted a pair of oval hoops 16 feet across, which in turn acted as a frame for the five

pairs of fairly flat wings. Two more wings were mounted on top of the pairs. The wings’ inboard sides were attached to a frame of five more ovals, and the engine—a 10-horsepower Buchet—was mounted on a pair of (what else?) circular frames. In the January 1909 issue of *Aerophile*, the Marquis likened the craft’s construction to “that of the big Ferris wheel of the [Paris Universal] Exhibition of 1900.”

There was no tail nor any control surfaces to speak of. Indeed, as the Marquis himself wrote, “It would be premature to speculate on how this machine would be controlled, insofar as its dynamic stability is so much more longitudinal than lateral.” There is also no record of its having flown, either before the June 1908 fire that damaged it or afterward, when the Marquis rebuilt it with 50 smaller wings. (Perhaps he had the same idea as Horatio Phillips: more planes, more lift, and worry about control later.)

It would be unfair to say all of these designs were losers. Some actually flew, and did so before the Wright brothers’ *Flyer*. A few even made tentative steps toward control. But Wilbur didn’t seem threatened by his competition. “From our knowledge of the subject,” he wrote to Chanute, “we estimate that it is possible to jump about 250 ft., with a machine that has not made the first steps toward controllability and which is quite unable to maintain the motive force necessary for flight. By getting up good speed a machine can be made to rise with very little power, and can proceed several hundred feet before its momentum is exhausted....”

While the Wrights were—well—right, their machine was a pretty sober affair. The designs of the pre-Wright era have a boldness and extravagance that make them easy to like and root for, however futilely. And maybe that’s instructive in its own right. —

The Marquis d’Ecquevilly’s multiplane made the Wrights’ designs look downright dowdy.





Looking skyward on a June day in 1945, Muscovites saw a huge four-engine aircraft enter a shallow bank for a landing at Izmailovo, a restricted sector in the northeast quadrant of Moscow where the Soviet navy's flight test facility was located. Startled onlookers watched the behemoth aircraft lower its landing gear for final approach. Red stars on the wings and fuselage signified that the intruder was friendly, though eagle-eyed observers might have noticed the English words "Ramp Tramp" on the nose section.

At the controls was one of the Soviet navy's top test pilots, Semyon Reidel, along with a skeleton crew of only two airmen: a copilot and an engineer. Once Reidel crossed the tree-lined outer perimeter of Izmailovo, he guided the aircraft to a smooth

BY VON HARDESTY | OF COURSE THEY COPIED IT. THE TWO AIRPLANES COULD HAVE BEEN TWINS. BUT WAS THE SOVIETS' TU-4 TRULY AN EXACT DUPLICATE OF THE BOEING B-29?

landing, completing an aerial trek that began in Vladivostok and crossed 11 time zones.

If *Ramp Tramp* appeared to Muscovites as a mysterious craft that summer day, the aircraft would not have been a stranger to Captain Howard R. Jarrell and his bomber crew. This was the same B-29 Superfortress they had flown to Vladivostok for an emergency landing on July 29, 1944, where it became the first of three B-29s to be interned by

the Soviets that year. Workers at Boeing's Wichita, Kansas plant could have identified it as B-29-5-BW (U.S. Army Air Forces serial no. 42-6256), part of an early production run of Superfortresses assigned to the 20th Air Force in Chengtu, China, for operations against Japan. But this B-29 would never return to U.S. soil.

Ramp Tramp was flown to Izmailovo because Soviet leader Joseph Stalin wanted a B-29 to serve as a template for a new heavy bomber to be produced in massive numbers in just two years: the Tu-4. Such a high-stakes scheme in technology transfer, if successful, would recast the Soviet air force into a strategic air arm and pave the way for military parity with the West in the uneasy peace that followed World War II. By copying the B-29, the Soviets would have an in-

MADE II



DMITRY SUBOLEV

Interned at Vladivostok on Stalin's orders, B-29s spawned the Tu-4.

tercontinental bomber capable of striking New York City and the industrial heartland of the United States—and in a fraction of the time it would take them to develop their own design.

Ramp Tramp first entered Soviet territory while returning from a raid in Manchuria. Jarrell's crew experienced electrical system problems and were saddled with a radio that would receive but not transmit, so Jarrell headed toward Vladivostok, where he naively assumed that he and his crew would be allowed to fly home as soon as the bomber could be repaired and refueled. Like many U.S. airmen, he thought the Soviets, then allies in the war against Germany, would welcome him and his crew.

But Vladivostok proved to be hostile territory. Ever since Edward York landed his B-25 at Vladivostok after the Doolittle Raid on Tokyo in April 1942, all U.S. aircraft penetrating Soviet airspace in the Far East had been confiscated. After landing in Vladivostok, Jarrell never saw the airplane again. He and his crew members joined other interned airmen in a camp in central Asia, where they remained for months, prior to being repatriated through Iran.

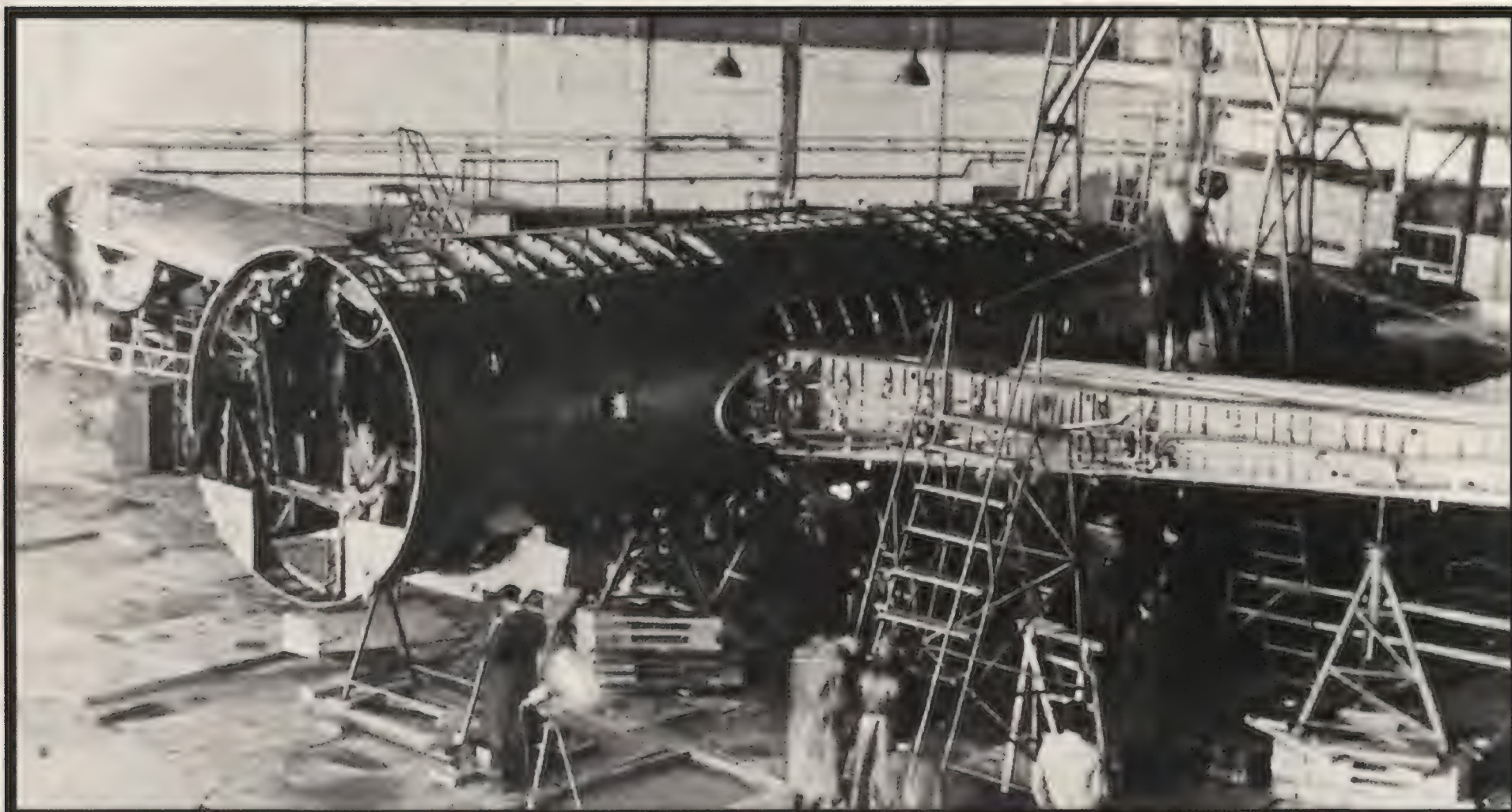
The Soviet decision to retain the American B-29s reflected one of Stalin's wartime priorities: the maintenance of a tenuous peace with Japan. Moscow could ill afford a war on two fronts with Axis powers. When Jarrell's crew landed at Vladivostok in the summer of 1944, the Red Army was still engaged in a titanic struggle with Nazi Germany. Stalin feared

that any overt cooperation with the United States in the Pacific War would be viewed by Tokyo as a military provocation, and the poorly defended Soviet garrison at Vladivostok was in easy reach of Japanese armies in Korea and Manchuria. Stalin would not enter the war against Japan until he could do it on his own terms, and not until August 1945, after the defeat of Germany.

During 1944 and 1945 deep differences and conflicting interests began to surface among the Allies, and these would shape the character of the war. Washington quietly acquiesced to the confiscation of the B-29s and kept the matter under wraps. There was no concerted diplomatic effort to gain their return, as maintaining cordial relations with Moscow was a high priority for the United States throughout World War II. The

SOVfoto





DMITRY SOBOLEV

Confirming what has long been surmised, this photo of the Soviets' secret B-4 project hangar shows the General H.H. Arnold Special at the Central Aerodrome in Moscow, with workers disassembling it piece by piece to copy its parts.

VLADIVOSTOK PROVED TO BE HOSTILE TERRITORY. EVER SINCE APRIL 1942, WHEN EDWARD YORK LANDED HIS B-25 THERE AFTER THE DOOLITTLE RAID ON TOKYO, ALL U.S. AIRCRAFT PENETRATING SOVIET AIRSPACE IN THE FAR EAST HAD BEEN CONFISCATED. AFTER LANDING IN VLADIVOSTOK, ITS CREW NEVER SAW THE AIRPLANE AGAIN.



NASM

The General H.H. Arnold Special had flown a number of missions from its base in China prior to a final, fateful mission to Manchuria.

War Department even asked returning interned airmen to keep silent about their sojourn in the Soviet Union. *Ramp Tramp* landed in Vladivostok at the very time in the war when friction between the Soviets and the Allies first emerged.

If relations with Moscow were difficult in 1944, they deteriorated further as the Allies advanced into Nazi

Germany in 1945. *Ramp Tramp's* appearance at Vladivostok coincided with Operation Frantic, during which U.S. bombers landed in the Soviet Ukraine after raids deep in Nazi territory. This joint operation aroused Soviet suspicions about U.S. motives, and the Allied conferences at Yalta and Potsdam in 1945 only sharpened a growing estrangement between the United States and the Soviet Union. Consequently, the "transfer" of three B-29s to the Soviets at Vladivostok became a fait accompli. No one in Washington could have anticipated that these same aircraft would play a critical role in the transformation of Soviet air power within two years.

The first time the Soviets got any public word of the B-29 was on the occasion of a visit by famed American ace Eddie Rickenbacker in 1942. Rickenbacker, who spoke openly about the new bomber, only confirmed what Soviet intelligence al-

ready knew from its own collection of manuals, photographs, and purloined technical materials.

Stalin had made three overtures to the United States under the Lend-Lease Act, a U.S. program launched in 1941 to provide materiel to friendly nations, to get B-29s as part of a general initiative to obtain heavy bombers. Washington rejected all requests for the heavies, but was generous with medium bombers, fighters, and transports. The Soviets even attempted a ruse in 1943, adding the B-29 to a long list of aircraft it wanted, but amused Lend-Lease officials denied the request.

Soviet air power surpassed the Luftwaffe to become the most lethal tactical air arm of World War II, employing fighters and ground attack craft organized into vast air armies as part of the general offensive against Germany in 1944 and 1945. By spring 1945, the Soviet air force had amassed enormous striking power, with as

many as 15,000 operational aircraft. But the Soviets were utterly lacking in strategic capability: Estimates said they could muster only 32 serviceable four-engine bombers—the outmoded and highly unreliable Pe-8. They therefore viewed the unexpected arrival of three B-29s on their soil as an extraordinary windfall, described as a *dar Bozhii*, or “gift from God,” by bomber pilot Vasilii Reshetnikov in his memoirs.

Soviet air planners, and Stalin himself, had been impressed with the Allied bombing of Germany, and the B-29 pointed to the importance of strategic aviation in any future war. Now the interned aircraft offered the Soviets their first opportunity to examine the most advanced U.S. bomber first hand. Stalin ordered Admiral Nikolai G. Kuznetsov, People’s Commissar for Naval Affairs and Commander of the Soviet navy, to begin flight tests. (The Superfortresses had landed at Tsentral’naya uglovaya, a Pacific Fleet air base, hence the navy’s jurisdiction.)

Kuznetsov appointed Lieutenant Colonel Semyon Borisovich Reidel to spearhead the test program. Throughout 1944 and 1945, Reidel, a pilot and engineer, had amassed an impressive number of hours ferrying Lend-Lease aircraft to the front, and he gained wide respect as the deputy director of the naval flight test program during the war. His knowledge of English became useful when he and his team studied U.S. technical literature, including several manuals found aboard the interned B-29s.

Reidel had only a few weeks to study *Ramp Tramp*, its instruments, and its anticipated flying characteristics. Using an English dictionary, he and a group of technicians made a detailed inspection of the Superfortress, re-labeling each switch and system. On January 9, 1945, Reidel, with A.F. Chernov in the right seat, flew the airplane to a base near Romanovka. Two days later, V.P. Marunov, another understudy, made a short flight. For days the three test pilots, taking turns in the left seat, perfected their skills at the controls. Romanovka, with its long runway and flat, unobstructed terrain, was a for-

giving environment in which to cope with an emergency, but the tests were completed without incident.

Kuznetsov, awestruck, sent Moscow an enthusiastic report. The lavish use of lightweight aluminum alloys, pressurized crew compartments, remote-controlled guns, powerful supercharged engines, Norden bombsight, radar, electronics, and instrumentation—all represented an advanced level of technology beyond Soviet industry’s reach.

Such reports only strengthened Stalin’s resolve to create a strategic air arm, and he called for the transfer of *Ramp Tramp* to Moscow. Accordingly, on June 22, 1945, the Soviets formally launched the B-4 program—a “bomber with four engines.” The B-4 (soon to be renamed the Tu-4) was to be an exact copy of the B-29 Superfortress.

Stalin simultaneously cancelled the Samolet 64 (“Airplane 64”) program, a new long-range-bomber project that had been launched in January 1945 with Andrei Tupolev as lead designer. Stalin had jailed Tupolev in the late 1930s on the improbable charge of aiding the Nazis in the design of the Messerschmitt Bf 110, but now Tupolev found himself elevated to a position of prominence as the head of a crash program. He accepted the assignment reluctantly, but he had no choice: Stalin had spoken.

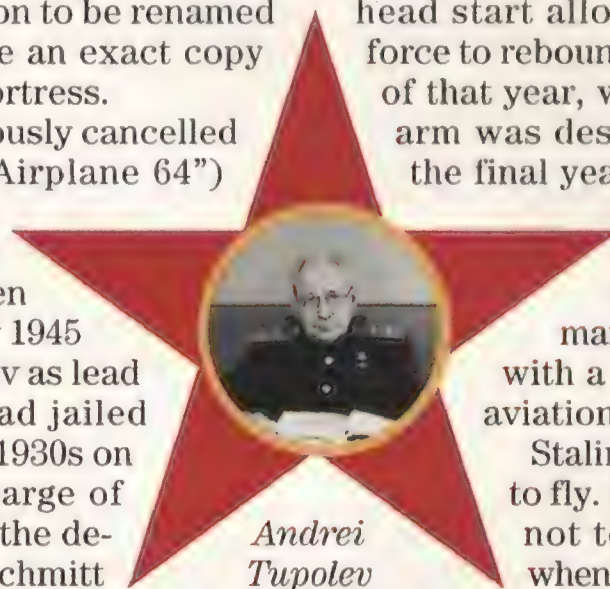
Stalin launched the project with a purge, which always preceded a change and most often victimized the most loyal figures. So it would be in this case, as he removed A.I. Shakurin, wartime head of the aviation industry, and Air Commander Alexander Novikov, a war hero, accusing them of sabotage for the criminal failure to provide the technical means for a long-range bomber. Shakurin and Novikov were exiled and humiliated, but neither endured a public trial or faced the prospect of execution. Novikov’s fate struck many within the Soviet air force as both ironic and cruel. A champion of both tactical and strategic aviation, he had em-

phasized the former because of the contingencies of the war. But Novikov had made some enemies. The once proud fleet of the bomber force shrank to only one unit: the 18th Air Army. This earned him the enmity of Air Marshal Alexander Golovanov, soon to be appointed by Stalin to head the expanding strategic air arm.

Stalin’s personal interest in aviation could be traced to the early 1930s, when he first patronized the aviation industry with huge government subsidies. In 1940 he reorganized military aviation from top to bottom, calling for a new generation of fighters and ground attack aircraft. Their development was already in motion on the eve of Operation Barbarossa, the 1941 Nazi invasion of Russia, and the head start allowed the Soviet air force to rebound from the disasters of that year, when most of its air arm was destroyed in place. In the final year of the war, Stalin again mobilized his beleaguered aircraft designers, plant managers, and air force with a new goal: strategic aviation.

Stalin himself was afraid to fly. In fact, he preferred not to travel at all, and when he did, it was aboard a carefully inspected limousine or special train. The Teheran conference in 1943 posed a problem for his train because Iran’s track gauge was different. Two Lend-Lease C-47s were flown from Baku to Moscow for the impending flight, one piloted by Air Marshal Golovanov, the other by Lieutenant Colonel M. Grachev. After greeting the pilots, Stalin said, “So, who will fly me to Teheran? Perhaps it would be better for me to fly with Colonel Grachev. Air marshals do more work behind desks than in the cockpit.” Stalin shook Grachev’s hand after the flight, and a promotion quickly followed.

What we know about the building of the Tu-4 is based largely on the writings of the late Leonid Kerber, whom I first interviewed in 1991. Kerber specialized in radios and navigation instruments, and he



Andrei
Tupolev

worked at Tupolev's side throughout the 1930s. Kerber wrote a first-hand account of the Tu-4 project, a story he told in an unofficial biography of his boss, *Tupolevskaya sharaga* ("Tupolev's Prison Workshop," reprinted as *Stalin's Aviation Gulag*, Smithsonian Institution Press, 1996).

Kerber's work first appeared in the early 1970s as part of the dissident underground press, or *samizdat*. Kerber's account of Tupolev's career included a candid recollection of the B-4 program: Tupolev initially thought the effort to copy the B-29 would be foolhardy. He was more confident that his own Samolet 64 had greater potential to surpass the B-29 in critical categories of range and payload, and his ego resisted the slavish copying of some foreign design. Tupolev wanted to incorporate the West's latest technology in an airplane that would represent the maturing technological expertise of the Soviet system. On this crucial matter he did not prevail, although the new B-4 bomber eventually bore the name Tupolev.

Stalin demanded that his new bomber be an exact copy of the B-29 because he wisely understood that even one concession would lead to a cascade of modifications, and any request to depart from this discipline would slow the process. Eager to maintain formal compliance with Stalin's order, Tupolev chose not to take the mandate literally despite the presence of the secret police and the possibility of denunciation, reasoning that Stalin's order pointed more toward ends than means. Throughout the first year of the Tu-4 program, Tupolev walked a tightrope between Stalin's requirements and practical concessions.

Tupolev chose not *Ramp Tramp* but the *General H.H. Arnold Special* (serial no. 42-6365) for disassembly. The work took place at the legendary Central Aerodrome at Moscow, in the only hangar large enough to hold it. A second B-29, the *Ding How* (no. 42-6358), was ordered grounded to serve as a reference. Only *Ramp Tramp* would continue to fly, and Tupolev sent it to the air force flight test center at Zhukovsky.

Ramp Tramp was transferred to

the Soviet air force on July 1, 1945, and, on orders from Air Marshal Alexander Golovanov, assigned to the elite 890th Air Regiment at Orsha. This special unit boasted the greatest number of pilots with flight experience in U.S. aircraft, and its fleet included 19 B-25s, 12 B-17s (F and G models), and one B-24.

Many of the airplanes had the customary U.S.-style nose art, and political commissars attached to the 890th often criticized this sign of decadence—images of scantily clad women were considered vulgar. Several of the airplanes' noses were painted over, though one Soviet pilot, I. Ikonnikov, who flew a B-17F in the 890th, remembered that a nose art image of a rabbit with a bomb had struck the commissars as uncontroversial and had been spared. At Orsha, the nickname "Ramp Tramp" puzzled many Soviet pilots and engineers, even those familiar with English. One rough translation offered was "Unshaven Vagabond," which still baffled Soviet airmen.

Later that summer, two prominent Soviet test pilots, Mark Gallai and N.A. Ischenko, flew a series of demonstration flights in *Ramp Tramp*. Gallai, along with another pilot, N.S. Rybko, enjoyed enormous prestige with the elite Soviet test pilot fraternity. Gallai came from a Jewish family, which might have been a problem for career advancement under the Soviet system, but his manifest skills as a pilot and engaging personality won him respect everywhere. His flight log included some of the most important aircraft of the period after World War II: He flew the initial flight of the MiG-9, the first Soviet jet fighter, and he participated in the acceptance program for the MiG-15 jet fighter. Gallai flew more than 200 types of aircraft, even taking the controls of the Luftwaffe's dangerous Me 163 interceptor.

Gallai flew these demonstration flights at the air force flight test facility at Zhukovsky, some 20 miles east of Moscow, where experts made a close inspection of the Wright R-3350 engines. Later they would refit *Ramp Tramp* with Shvetsov ASh-73TK engines, the Soviet clone of earlier Wright engine designs that had been

acquired under license and for which parts were available.

Tupolev's first inspection of the *General H.H. Arnold Special* occurred on the night of July 10, 1945, marking the formal start of the B-4 project. During the inspection the hefty Tupolev got stuck in the duct between the forward and aft pressurized compartments of the bomber. He joked later that the Americans apparently did not feed their airmen properly.

Teams of engineers, technicians, and rigging specialists, swarming like worker bees, descended on the airplane. The process was slow and systematic. Each component was measured and photographed for replication. Instruments and controls were carefully removed and the placement of hydraulic lines and wiring marked. Every part and subassembly was numbered, labeled, and recorded. The components were then assigned to a design team for reproduction.

During this process, Kerber discovered a plaque next to the bombardier's seat that read: "At the request of the workers of the Boeing plant in Wichita, Kansas, this B-29 is named the General H.H. Arnold." The plaque commemorated an inspection tour Arnold made of the Wichita plant in 1942, and it prompted some debate among the technicians at the Central Aerodrome. They marveled at the apparent solidarity of the workers with a high-ranking American officer, which ran counter to Soviet propaganda on the nature of class struggle in the United States. Kerber eventually gave the plaque to the son of a colleague, Boris Saukke, and the Saukke family still has this sole surviving artifact from the three B-29s at Vladivostok.

Stalin maintained control over the Tu-4 program through Lavrentiy Beria. The fellow Georgians would often break into their native dialect, with devastating effect on intimidated officials. Beria fully embraced the regime's cruelty and headed Stalin's most critical programs, including the atomic bomb. Beria came to Moscow in 1938 to head the NKVD—the se-



THE PROCESS WAS SLOW AND SYSTEMATIC. EACH COMPONENT WAS MEASURED AND PHOTOGRAPHED FOR REPLICATION. INSTRUMENTS AND CONTROLS WERE CAREFULLY REMOVED AND THE PLACEMENT OF HYDRAULIC LINES AND WIRING MARKED.

cret police. He presided over purges, expanded the gulag, and moved up once the war began to serve on the Central Committee of the Communist Party and as deputy prime minister. Stalin even made him a marshal of the Soviet Union. But Beria's most important post was inside the State Defense Committee, where he oversaw key programs associated with state security. He would cast a long shadow over the Tu-4 program.

Beria evoked fear in all quarters, even among high-ranking party and military figures, but he displayed no small amount of skill in coordinating secret programs. Toward his peers Beria could be rude and threatening, but he frequently displayed politeness to subordinates, especially Tupolev. For Beria, the bottom line was always accountability. Those who performed their tasks on time and to the standards he expected enjoyed relative safety. His efficiency and loyalty earned Stalin's trust,

which endured until the dictator's death in 1953. Only then did Beria become vulnerable, and he was executed that December.

As administrator, Tupolev enjoyed Stalin's imprimatur, which afforded unique access to Soviet industry. Tupolev's return to favor also signalled the decline of his chief rival, Alexander Yakovlev, along with those tied to the expansion of Soviet tactical aviation during the war years. Still,

Tupolev found himself at a dangerous crossroads. He understood that success would consolidate his position and could even open up vast opportunities in the postwar aeronautical community. But failure might cast him into yet another uncertain

relationship with a ruthless Joseph Stalin and even lead to imprisonment.

In this context, Tupolev's skill as a manager would face its most severe challenge. While flight tests of *Ramp Tramp* proceeded, he recruited his administrative team for the Tu-4



Mark
Gallai



Workers carefully measured and registered each part (top) before it was sent out to a design team for reproduction. Such reverse engineering gave the Soviets a strategic bomber in record time.

project, naming Dmitry S. Markov as his chief deputy. A trusted associate of Tupolev, Markov possessed broad technical expertise and had earned a reputation for competence as a designer. Markov had served with Tupolev in the prison design bureau and knew U.S. aircraft technology first-hand, having worked with Soviet adaptations of a Vultee aircraft.



VLADIMIR RIGMANT

AS THE FIRST PARTS AND SUPPLIES FOR THE TU-4 BEGAN TO ARRIVE FOR INSPECTION, TUPOLEV DEvised A SPECIAL EXHIBIT IN MOSCOW TO DISPLAY PROGRESS GRAPHICALLY, NOTING DEADLINES MET AND MILESTONES STILL TO BE ACHIEVED—ALONG WITH THE NAME OF THE RESPONSIBLE MANAGER.

Markov later became known in the West for another high-priority cold war project, the design of the supersonic Tu-22M3 "Backfire" bomber.

Where Tupolev could be brusque and often vulgar, Markov was more gentlemanly. He maintained a low-profile role in the Tu-4 project, yet he was a hands-on manager who could motivate everyone to meet cruel deadlines. When it came to manipulating the system to reward workers with consumer goods and housing, Markov could rival his boss in the arts of maneuver and influence peddling. He won the enduring loyalty of all those caught up in the Tu-4 program and emerged in the postwar years as a beloved and respected figure in the Soviet aviation establishment.

Tupolev faced enormous problems setting up his organizational structure. He would rally some 64 design bureaus and over 900 factories, research institutes, and technical entities, keeping everything in motion

and assuring quality control. By agreement, Markov handled the day-to-day work of the project. Tupolev focused on mobilizing the war-weary aviation industry, the air force establishment, party officials, and key government ministries.

During the long war with Germany, the Soviet aviation industry had met Stalin's extraordinary demand for volume production. Now it was being asked to master complex systems and manage the copying of over 100,000 components, each of which had to meet weight requirements and arrive on time.

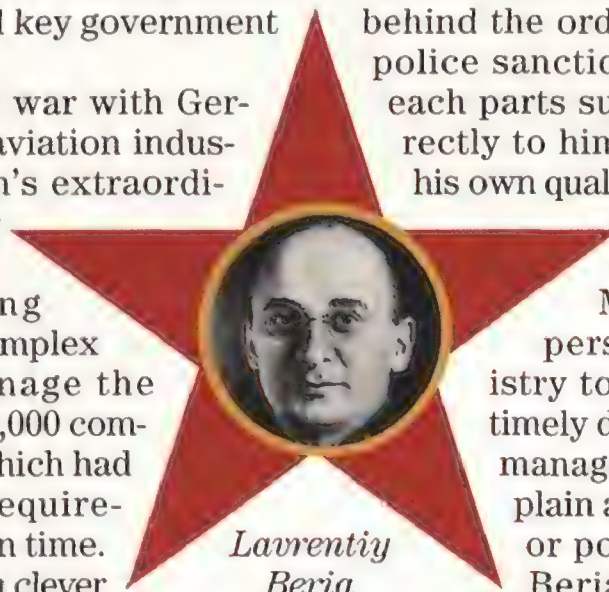
Tupolev devised a clever scheme to delegate responsibility. First, he sought out A. I. Mikoyan, then deputy chairman of the Council of Ministers, to assist with the problem of coordination. Tupolev did not want the parts sup-

pliers to report to him directly. Having the power brokers at the government ministry level order the parts allowed him to have the best of both worlds: the full power of the state behind the ordering of parts, with police sanctions as backup, plus each parts supplier reporting directly to him and responding to his own quality control mandates.

To implement this plan, he asked Mikoyan to appoint a person from each ministry to be responsible for timely delivery. Each project manager would have to explain any missed deadlines or poor workmanship to Beria. Mikoyan quickly agreed, appointing high-

ranking bureaucrats—often deputy ministers—to assume responsibility. (Later, Sergei Korolev used this same model for the Soviet space program.)

While Tupolev manipulated the pol-



Lavrentiy
Beria

itics, he never abandoned control of critical aspects of the program: He kept the calendar, and he was adept at trouble-shooting. Leonid Kerber remembered Tupolev's uncanny aptitude for anticipating trouble spots, and whenever problems arose, Tupolev would intervene directly. He also hired a talented coordinator in the person of I.M. Sklyanskiy. This choice proved to be inspired, if dangerous in the minds of Tupolev's nervous associates. Sklyanskiy was an engineer, full of energy, attentive to detail, and blessed with a keen memory. No other person was better suited to supervise the timetable, which filled one entire wall of a special exhibition located at Tupolev's design bureau on Radio Street in downtown Moscow. As dispatcher, Sklyanskiy filled out four cards for each part placed on order: one for Tupolev, one for the aviation ministry, another one for the cooperating ministry, and a final one for the actual manufacturing entity in the field.

Still, Sklyanskiy's past aroused some anxiety. He had once been arrested and spent some time in a police-run workshop not unlike Tupolev's *sharaga*. This was not unusual, but it did place him in great jeopardy whenever there was a failure or breakdown in the system. Worse, Sklyanskiy's brother had once served as Leon Trotsky's deputy on the Military Revolutionary Committee during the Bolshevik revolution. For reasons still unclear, this link with Trotsky, the regime's premier enemy of the people, never got Sklyanskiy into trouble.

As the first parts and supplies for the Tu-4 began to arrive for inspection, Tupolev devised a special exhibit in Moscow to display progress graphically, noting deadlines met and milestones still to be achieved—along with the name of the responsible manager. Booths for each major component or sub-assembly consumed two floors of his design bureau. Telephone links to the responsible factories provided the latest updates. The exhibit provided a convenient vehicle to showcase the project to visiting officials and alert Tupolev to any potential breakdown. When Stalin learned of this remark-



Tupolev's exhibition helped to explain the project to visiting officials while affording him a convenient means to monitor the massive program.



Detailed cutaway drawings, mockups, and even entire components such as the defensive cannon filled the design bureau's exhibition floors to capacity.



Landing gear proved a challenge to engineers, as did the huge tires.



Technicians updated exhibits daily and weekly to track progress.

able exhibit, he planned a visit.

Any tour by the boss stirred high anxiety, and Stalin picked a Sunday, when the plant was closed. This was not unusual; he often made late-night phone calls to distant offices, forcing fearful bureaucrats to remain in their offices around the clock. On the afternoon of Stalin's visit, Tupolev and his staff gathered at the plant. Teams of police in civilian clothes arrived, searched the building, locked all the doors, substituted their own guards for the plant security force, and set up their own sentry posts. For these critical briefings, there were precise instructions. All briefings should be short and comprehensible. At no time should a briefer look away from Stalin's eyes, put his hands in his pockets or jacket, or ever position himself behind the leader.

The police instructed everyone to stand in place and not move without permission. Armed guards would escort anyone to the restroom. Outside, the streets had been cleared except for policemen dressed in civilian clothes, who strolled around to create the atmosphere of a normal Sunday afternoon. Hours passed, but after all these preparations, Tupolev announced to his exhausted staff at 2 a.m. Monday morning that Stalin had cancelled the tour. Everyone returned home in the black ZiS cars of the police.

The documentation required for the new bomber had been enormous. Retro-engineering dictated the analysis and photographing of some 105,000 parts. Tupolev's team generated 40,000 detailed drawings, completed by a force of a thousand draftsmen. Exacting quality standards and the threat of police sanctions made the whole enterprise an exhausting experience. During the most critical phases of the program, workers were sometimes allowed only one day off each month. Any deviation raised the fear that someone, for personal benefit or revenge, might complain to the police.

One immense challenge was the difference between English measurements used by U.S. manufacturers and the metric system, which the

Soviets used. Early on, Tupolev decided not to convert the U.S. units to the metric system, which would have been time consuming. The manufacture of aluminum panels exemplified the problem. The standard thickness of the aluminum skin on the B-29 was 1/16 of an inch (1.5875 millimeters). It was impossible for Soviet plants to fabricate metal sheets to that dimension. Tupolev opted to vary the thickness of the Tu-4's skin between .8 and 1.8 millimeters, which actually had the effect of strengthening the aircraft's structure in some areas. Despite such changes, the weight of the Tu-4 would turn out to be only one percent greater than the B-29. No less critical were other compromises made on electrical wiring as well as hydraulic pressure and fuel consumption.

While Tupolev remained attentive to certain external cosmetic flourishes to suggest strict compliance with Stalin's order for an exact copy (a repair patch in the fuselage was included and the interior paint scheme duplicated exactly), he often went his own way on the more critical, less obvious components. Stalin's acquiescence on the matter of using the metric system had been a major concession. Other concessions followed in engines, radar, and armament. Leonid Kerber aptly described the Tu-4 as an "analog" or, in this context, a facsimile of the B-29. If the airplane can be thought of as having a genetic code, the dominant genes were Boeing's, and the recessive genes were Tupolev's.

Among all the concessions, the choice of engines for the new Tu-4 became critical. Arkadiy Shvetsov, a Soviet engine designer, learned from Tupolev that he would not have to replicate the B-29's powerful 2,200-horsepower Wright R-3350 engine. Instead, Tupolev approved Shvetsov's request to fit the Tu-4 with a variant of the M-71 design (a Wright engine clone). The resulting ASh-73TK engine would boast 2,300 horsepower, but the Shvetsov design proved inadequate, at least in the initial production run, to match the performance of the Wright R-3350. There were constant problems with over-

heating and frequent propeller failures. The ASh-73TK design, however, was a sound one, and subsequent refinements eliminated problems.

Some duplication efforts led to surprising successes. One of the more complex units on a B-29 was the Central Station Fire Control System, the computerized remote firing system. Gunsights and controls were located with the gunners in Plexiglas blisters and were linked electronically to remote turrets housing the guns. The system incorporated complex circuitry and switches that enabled any B-29 gunner to control any of the gun turrets that he could aim properly. I.I. Toropov devoted his considerable talent and energy to this system. He succeeded, to the amazement of Tupolev and the consternation of observers in the West, who believed this advanced system was beyond the capacity of the Soviets.

No less important was the decision to substitute the Soviet NS-23 cannon for the original .50-caliber machine guns, another concession approved by Stalin. Tupolev also contended with a bomb bay that was larger than any produced in the Soviet Union. And there were enormous problems with the system that actuated the undercarriage, along with the inability of the Soviet aviation industry to produce the oversize tires for the landing gear. When faced with the task of copying the B-29's large tires and complex gear, the Soviets used a unique approach: Agents were sent to the West to purchase them on the war surplus market.

Many myths have arisen in the West about how the Soviets built the Tu-4. Over the decades stories have circulated that the B-29 was copied in exacting and often ludicrous ways. These tales suggest that Tupolev and his team mindlessly replicated every aspect of the Boeing design. As noted, Tupolev did approve the precise copying of such details as a fuselage patch and the exact hue of the interior paint scheme found on *Ramp Tramp*. Some rumors circulated that even flak damage on the wings had been carefully copied, but such stories exaggerate what actu-



A modified Ramp Tramp continued to fly for the Soviet air force after World War II, but maintenance posed problems.

THE NICKNAME "RAMP TRAMP" PUZZLED MANY SOVIET PILOTS AND ENGINEERS, EVEN THOSE FAMILIAR WITH ENGLISH. ONE ROUGH TRANSLATION, "UNSHAVEN VAGABOND," STILL BAFFLED SOVIET AIRMEN.



Among its missions: mothership for the Soviets' 346 research aircraft.



Ramp Tramp carried the rocket-powered 346 to drop altitude for test flights, just as its cousins back home trundled aloft with the Bell X-1 and others.

ally happened.

When I interviewed Leonid Kerber in 1991, he told me that these stories were partially true, although he felt Westerners did not understand the historical context or Tupolev's motives. All these minor details in copying, according to Kerber, were a way to prevent Beria's police from accusing the Tupolev team of ignoring Stalin's precise instructions. No one wanted to risk arrest.

Aside from the threat of imprisonment, Tupolev had to contend with the legendary bureaucratic inertia associated with the aviation industry. For decades, Soviet designers

had come up with excellent aircraft designs, even prototypes, only to see serial production fall short of the design standards. Soviet aviation plants had trouble sustaining quality control in the mass production of aircraft. The more complex the aircraft, the more disappointing the result. It was easier in the war years to build huge numbers of military aircraft of simple design, such as 33,000 Ilyushin Il-2 Shturmovik ground attack aircraft known for their sturdiness and austere instrumentation. Such aircraft could be built using a largely unskilled labor force. The Tu-4 demanded a level of sophistication at

odds with decades of industrial practice, and to a degree no Westerner might have expected, the Soviets succeeded. The first batch of Tu-4s rolled off the assembly line on schedule in 1947, less than two years after the project was launched—an incredible feat. As production expanded, additional plants were mobilized.

Tupolev selected three prominent test pilots to fly the first operational Tu-4s off the assembly line—Nikolai S. Rybko, Mark Gallai, and A.G. Vasil'chenko—and Rybko received the nod to make the maiden flight, scheduled for May 1947. Po-

lice security was tight, but once word of the flight leaked, workers streamed to the edge of the airstrip near the plant. The workers had made enormous sacrifices, and no one wanted to miss the first flight. Thousands crowded the roads and the outer boundary of the plant's airfield to get a glimpse. When Rybko lifted the new Tu-4 into the air, the workers cheered.

Kerber tells of being the passenger on a later flight in which Mark Gallai flew a new Tu-4 from Kazan to Moscow. During the flight, hot air filled the pressurized compartments, and no one could get the air conditioning to work. Kerber remembered the embarrassment of cancelling the welcoming reception because the sweat-soaked passengers looked as "if they had just walked in from the Sochi beaches."

The Tu-4 made its public debut on Aviation Day in August 1947, at Moscow's Tushino airfield. Foreign observers, including the Western powers—particularly their military attaches—were all invited. Three Tu-4s, followed by a Tu-70 passenger version, flew by at 600 feet. At the controls of one of the Tu-4s was Air Marshal Golovanov. When the Western observers counted three bombers, they assumed the Soviets were flying the long-lost interned B-29s. But the appearance of the Tu-70 clearly indicated that the Soviets were flying freshly cloned B-29s. This carefully staged event became a headline story in Western newspapers, though few realized how narrow the margin had been to get these four airplanes airborne. The Tu-70 had been fitted with cannibalized parts from the disassembled *General H.H. Arnold Special* to make it airworthy.

Operational deployment of the Tu-4 brought a series of breakdowns and near disasters as the airplane encountered teething problems such as engine overheating, a glitch that mirrored the U.S. experience with the first generation of B-29s. Soviet engineers fretted over numerous other problems such as runaway props, de-

icing system failures, and chronic failures of the landing gear.

Rafael I. Kapreytan, one of the first to fly the new bomber, could not get his landing gear to extend fully on one flight but managed to make a successful landing on his starboard main gear, saving himself, his crew, and the aircraft. Vasil'chenko, the test pilot, faced an engine fire. Fearing the worst, he ordered his crew to parachute to safety; after nine of the 11-man crew bailed out, the fire died and he was able to land the bomber safely. In time, these problems would be corrected, but in the early days of the program the Tu-4 inspired little confidence.

The Tu-4 became truly operational in 1948 and 1949, as production reached full capacity. By 1950 Soviet Long Range Aviation had deployed nine Tu-4 regiments, each with 32 bombers.

NATO assigned the Tu-4 the code name "Bull." In the early 1950s the Soviet Union sent a batch of Tu-4As to the People's Republic of China. This move gave the Chinese a credible bomber force for the first time. A contingent of about 32 Tu-4s was deployed in the Soviet Far East

to serve in the reconnaissance role, and during the Korean War the number of Tu-4 bombers increased dramatically; recently uncovered archives number the fleet at 845 aircraft.

The Soviets detonated their first nuclear device from a tower on August 29, 1949. As soon as they perfected the bomb, Stalin approved high-priority experiments to adapt the Tu-4 as its airborne delivery system. On October 18, 1951, a Tu-4 bomber dropped an atomic bomb near Semipalatinsk. It would not be until November 1955 that a Soviet bomber, in this case a Tu-16, dropped the first Soviet H-Bomb. For NATO observers, these events confirmed the Soviet Union's enhanced capabilities in strategic aviation.

The West reacted with increasing alarm. The Tu-4 never possessed the range to pose a real threat to the Unit-

ed States—only a one-way mission could threaten Chicago or New York City—but the very existence of the Tu-4 and its jet-powered successors prompted the United States to set up an array of defensive systems, including the Nike surface-to-air missiles and the Skysweep radar-guided anti-aircraft guns of the 1950s.

The Soviets also experimented with the Tu-4 as a tanker for aerial refueling, and several systems were tried before the perfection of a probe-and-drogue system in October 1952. Eventually this system was used for refueling MiG-15 jet fighters in an effort to expand the striking range of the Soviet air force. With the advent of the Jet Age, the Soviets realized that the Tu-4 was obsolete, a perception reinforced by the losses in combat of American B-29s in the Korean War.

Only once in the cold war years of the 1950s did the Soviets threaten to deploy the Tu-4 in combat, although the details are unclear. In the first hours of the Hungarian Revolution of 1956, at a time when party secretary Nikita Khrushchev and the Soviet military were debating the options to counter a revolt in Hungary, several Tu-4 bombers were ordered to drop conventional bombs on Budapest. Saner minds prevailed, and the flight was called back while en route to the Hungarian capital, leaving Soviet ground forces and tanks to resolve the problem. This aborted flight remains one of the more controversial episodes associated with the history of the Tu-4.

Ramp Tramp flew for nearly a decade, and soon acquired a legendary status among bomber crews as the progenitor of the Soviet strategic air arm in the early years of the cold war. Many Soviet bomber pilots in the early stages of the Tu-4 program took enormous pride in the fact that their flight log included hours on the Superfortress from Wichita.

There had even been one brief period when *Ramp Tramp* was employed as an airborne carrier for a Soviet X-plane, the rocket-powered Samolet 346. In May 1947, former German test pilot Wolfgang Ziese took off in the bomber with the 346 attached to its starboard wing. At



high altitude, he released the 346, which achieved an estimated speed of Mach 0.93—at that time the most serious effort by the Soviets to break the sound barrier.

But despite a refitting with Shvetsov engines and numerous upgrades, *Ramp Tramp* was becoming increasingly difficult to maintain. By 1954, the Tu-4 fleet was gradually being dismantled, and the U.S. bomber was scrapped along with it. Today, at the Monino air museum outside Moscow, a lone Tu-4 bomber stands outside on display, the sole reminder of a turbulent time.

Stalin's decision to copy the B-29 allowed the Soviet Union to acquire an interim long-range bomber, if not a true intercontinental strategic weapon. The Tu-4 enabled the Soviets to project power credibly on the front side of the Cold War, at a time when the worsening relations with the United States and the advent of nuclear weapons posed what they

perceived as serious threats to their national survival.

There was a second aspect to these events, one less visible to many in the West. The Tu-4 project became the pathway for the rapid modernization of the Soviet aviation industry and gave expression to Stalin's larger purpose: providing for Soviet national security, even military parity with the West. In the Tu-4 program, Stalin demonstrated a certain truth about the Bolsheviks: Personal ruthlessness did not necessarily preclude shrewdness or a disciplined flair for survival. While his instincts were not always perfect, Stalin nevertheless possessed a remarkable strategic sense—including an eye for the right airplanes—that shaped all his policies.

Stalin reorganized Soviet aviation for the post-war environment, compelling it to adopt a range of new technologies, materials, and techniques of manufacture. Technologi-

cal inferiority persisted, but the baseline for a more sophisticated aviation sector had been established.

The success of the Tu-4 program cannot be separated from Tupolev's persona—a rare blend of design and administrative talents. His leadership demonstrated that the relatively primitive aviation industry could be recast to build modern aircraft on a par with those of the West. His success with the Tu-4 program, as many Russian historians acknowledge today, provided a model and an inspiration for Sergei Korolev in the missile and rocket program that was to follow. In its own way, *Ramp Tramp* had offered the Soviet Union a trajectory to the future. —

This article was prepared in consultation with Russian historian Dmitri Sobolev, and with the assistance of V. P. Kotel'nikov, Aleksei Drozhilov, Vladimir Rigmant, Gene Eisman, Michael Moore, and Ilya Grinberg.

IN THE TU-4 PROGRAM, STALIN DEMONSTRATED A CERTAIN TRUTH ABOUT THE BOLSHEVIKS: PERSONAL RUTHLESSNESS DID NOT PRECLUDE SHREWDNESS OR A DISCIPLINED FLAIR FOR SURVIVAL. HE POSSESSED A REMARKABLE STRATEGIC SENSE—INCLUDING AN EYE FOR AIRPLANES.

One of few surviving Tu-4s stands outside the Monino Museum near Moscow; all three U.S. B-29s were scrapped.



VLADIMIR RIGMANT



▶ SIGHTINGS ◀

When landscape photographer John Sexton first began thinking about photographing the space shuttle—as part of a project to portray human technological achievements rather than natural vistas—he worried that the shuttle might not affect him as deeply as other subjects had. “Would it make my heart beat faster, as Hoover Dam had, because of its scale and complexity?” wondered Sexton, who had worked for Ansel Adams in the late 1970s.

He first visited Kennedy Space Center’s Orbiter Processing Facility, where *Endeavour*’s rear landing gear impressed him with its simple, utilitarian design (bottom left). “If you put the gear in a gallery, it would be an interesting sculpture in itself,” he says. This was one of the first images Sexton made during the project—featured in his new book *Places of Power*—and it settled his fears about whether the shuttles would make good subjects.

Elsewhere at Kennedy, the solid rocket booster parachutes attracted Sexton with their flowing shapes, shimmery white fabric, and complex design (top left). But the real clincher came when Sexton walked into the Vehicle Assembly Building. “I realized how much the enormous interior space is like a cathedral, and I really wanted to have my cathedral include an altar piece,” he recalls. “Though the launch is more dramatic, the lift-to-mate procedure is a close second—but for every opposite reason. It’s a slow, precise ballet.” During one long night, he shot the four-minute exposure at right, which remains his favorite.



Rescue Mission

Air Battle Dunkirk

by Norman L. R. Franks. Grub Street, 2000. 224 pages, \$29.95 (hardbound).

Grub Street has made a name for itself publishing explorations of the creases and folds of aviation history. One of their latest offerings covers just eight days of aerial conflict during World War II. To those tempted to dismiss this book on grounds that such a small focus equals a boring read, do not.

Norman Franks has crafted an excellent book. His masterful use of personal accounts and oral history allows the reader to step at will from the cockpits of Royal Air Force Hurricanes, Spitfires, Defiants, and Hudsons to the laboratory of historical analysis and back again with ease. Readers will turn the last page prepared to answer the question voiced repeatedly by British soldiers and sailors at Dunkirk and echoed in the British press at the time: Where was the RAF?

Adolf Hitler's incomprehensible order halting the German army within 15 miles and one day of annihilating the British Expeditionary Force at Dunkirk set the stage for the subject of Franks' book. Rather than eliminating the British army



Early models of the Hawker Hurricane battled the Luftwaffe over Dunkirk.

with blitzkrieg (combining armored and infantry forces—supported by tactical air power—to conduct “lightning war”), Hitler heard the pleas of Luftwaffe chief Hermann Goering to destroy the BEF and remnants of the French forces huddled against the beaches at Dunkirk with air power alone. The British mobilized any watercraft that would float, and under nearly continuous attack by the Luftwaffe, rescued more than 338,000 beleaguered British and French troops.

Most of the book consists of action-by-action accounts of aerial combat tied together by the author's analysis. The participant's words also reveal how the pressures of aerial combat molded RAF fighter tactics. Weather conditions and visibility—and their impact on the battle—are also vividly described. Franks rarely steps back to describe or analyze broader issues. He does mention some of the political factors that

influenced the numbers of aircraft the RAF could commit to cover Dunkirk. He also notes a critical error in judgment by the deputy chief of the air staff, Air Marshal Sholto Douglas, that restricted the ability of RAF pilots to fight with maximum efficiency.

Franks sprinkles footnotes throughout this book, but these usually refer only to a pilot's fate after the Dunkirk operation. The appendices contain detailed loss/claim tables for RAF and Luftwaffe pilots, but a short summary comparing reported claims with actual losses for both sides is left for the reader to calculate. The index contains only the names of pilots. At less than 190 pages, readers may sprint through this latest offering by one of Britain's better aviation historians. It is an easy and interesting exercise.

—Russell Lee is a curator in the aeronautics department of the National Air and Space Museum.

CD

An Introduction to the National Air and Space Museum.

CD-ROM, \$20.00.

Both a source of screensaver art and an interactive map to 24 NASM artifacts. Includes more than 100 photographs of some of the most popular air- and spacecraft on display.



The Happy Bottom Riding Club: The Life and Times of Pancho Barnes

by Lauren Kessler. Random House, 2000. 320 pages, \$24.95.

Lauren Kessler's fine biography of Florence "Pancho" Barnes gives more depth to the well-known story of the brash, good-time hostess whose Mojave Desert resort provided R&R for hotshot Air Force test pilots flying in the late 1940s.

That's an accurate description of Barnes, of course, but don't forget that she soloed when Chuck Yeager was just five years old and was an accomplished pilot in her own right. In 1929 she flew 40 miles to win what was called the world's first women's air race, and that summer—as one of only 34 licensed woman pilots in the nation—competed in the first all-female cross-country race, which Will Rogers dubbed the "powder puff derby."

In August 1930, Barnes flew 196.16 mph to set the women's speed record, besting Amelia Earhart's month-old record. She also was the only woman included for membership when the Association of Motion Picture Pilots was chartered in 1932.

Kessler portrays Barnes' fascinating life with rich description. As a young heiress born in Pasadena, California, in 1901, Barnes was a rebellious child who, while enrolled in convent school, ran away on horseback to Tijuana at age 15. At 19, she married a clergyman and bore a son. The careers of this unlikely minister's wife included wrangling horses (and then airplanes) for the movies, screenwriting, songwriting, politics, farming, and even trying to practice law as her unhappy later years were plagued by courtroom appearances.

The legal details of divorces and land claim battles with the government don't make the most entertaining reading, but most everything else in the book is

ON TELEVISION

Test Pilots: Flying the Wing

Premieres Friday, February 16, at 10:00 p.m. on Discovery Channel.

Follows the creation and testing of the world's first stealth bomber, the B-2 Spirit. Includes interviews with engineers, pilots, and military strategists who explain how the big flying wing can evade radar detection.

FUTURE SPACE HARDWARE

Designs on Space: Blueprints for 21st Century Space Exploration

by Richard Wagner with illustrations by Howard Cook. Simon & Schuster, 2000. \$24.00 (hardbound).

Presented like a portfolio of a draftsman's pencil sketches, this handsome little book highlights vehicles that may launch early in the 21st century. Some, represented by the five proposed designs for a robotic Mars airplane, have already fallen victim to a tight NASA budget.



interesting. Barnes' grandfather, Civil War balloonist Thaddeus Lowe, is a wonderful character to get the narrative started, and the men she later hung around—including Yeager, Howard Hughes, Erich von Stroheim, John Wayne, and Jimmy Doolittle—keep the adventure going.

Barnes was known by the company she kept, but as Kessler's book shows, her own life story surely equalled that of any of her better known friends.

—Long-time Air & Space contributor Richard Sassaman writes from Bar Harbor, Maine.

The Day We Bombed Switzerland: Flying with the U.S. Eighth Army Air Force in World War II

by Jackson Granholm. Airlife, 2000. 246 pp., \$24.95 (hardbound; distributed in U.S. by Zenith Books, 800-826-6600).

As a university dropout and night machinist at Boeing Aircraft, young Jackson Granholm didn't get around to enlisting until July 1942. With equal leisure the Army Air Forces tried to make a pilot of him, then trained him as a navigator, and finally—in June 1944—sent him on his first mission.

His bomber was the slab-sided, four-engine Consolidated B-24 Liberator, which carried more bombs than the

fabulously handsome Boeing B-17. Ford Motor Company and others built 18,000 B-24s, and the AAF filled each of them with a 10-man crew.

Never mind the title—the book should be read for its day-to-day account of the lives and deaths of the men who carried the bombs to Germany. More than 300,000 Americans served with the "Mighty Eighth," and more than 26,000 were killed. Granholm sees some of them vanish, their B-24s consumed by fire or plunging wingless to earth. Between missions he goes to church, meets a charmingly ignorant showgirl named Valerie, and discovers that one of the officers at headquarters doesn't know that the world is round.

Granholm and the flat-earther join forces in a court-martial alluded to in the title, defending a pilot and a navigator who had the bad luck to choose Zurich as their "target of opportunity." (The president of the court is actor-airman Jimmy Stewart.) The fate of the defendants turns on whether their mistake was a reasonable one.

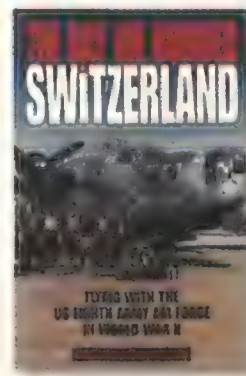
"I found myself wondering," Granholm

writes, "whether 'reasonable' was the right word for [men who flew] great, monstrous aeroplanes over Germany every day to drop high explosives. It was a sense of duty that sent us out, not reason. A

reasonable person

wouldn't have walked within five hundred feet of a B-24 bomber."

—Daniel Ford's most recent book, *Remains*, is about the *Flying Tigers* of World War II.



AUDIOBOOK

Schirra's Space

by Wally Schirra with Richard N. Billings. Naval Institute Press Audiobooks, 2000. Four cassettes, \$29.95.



This audio version of Wally Schirra's 1988 book is peppered with anecdotes about Schirra's career as a Navy pilot, which started in the cockpit of a biplane trainer and culminated with Mercury, Gemini, and Apollo missions.



Rowan's Battle of Britain. Empire Interactive, (800) INTERPLAY, www.empireinteractive.com, \$49.95.

Rowan's *Battle of Britain* (above) portrays the Luftwaffe's ill-fated attempt to destroy the Royal Air Force during the summer of 1940. Players have the option of either flying for England or Germany and can even direct the air war by taking command of either side. What makes this game—to be released this year—truly remarkable is that the developer plans to recreate some of the biggest raids over England, with some missions containing dozens of squadrons and over a thousand aircraft. Five flyable aircraft types will be modeled, including the Luftwaffe's Bf 109 and Bf 110 fighters, the RAF's Spitfire and Hurricane, and the Ju 87 dive-bomber. Furthermore, players can slip behind the gun positions of the Dornier Do 17, Heinkel He 111, and Junkers Ju 88 bombers, although they'll have to rely upon the computer to fly these airplanes.

B-17 Flying Fortress 2: The Mighty 8th. MicroProse, (800) 400-1352, www.microprose.com, \$49.95.

Developed by England-based Wayward Design, *FF 2* lets players take part in some of the most crucial missions of the war, including the combined raids on Regensburg-Schweinfurt and the ever-hazardous bombing of Berlin. Players are able to plan their own missions from start to finish, choosing from any one of over 200 targets to bomb. Several playing modes are offered, including a long list of historical stand-alone

missions. *FF 2* also contains a dynamically constructed campaign game, in which the player is graded on mission performance and successful fulfillment of the Eighth Air Force's strategic plans. The player can serve as a bomber commander, responsible for a single airplane and its crew, or he can be a squadron commander,



handpick the crews for a 12-ship bomber squadron, and lead it into battle.

While the lack of a multi-player mode is certainly a disappointment, *FF 2* nevertheless provides a telling look at the perils and pitfalls of daylight bombing during World War II.

Combat Flight Simulator 2: WWII Pacific Theater. Microsoft, (800) 426-9400, www.microsoft.com, \$34.95.

Apparently, Microsoft listened to the critics who said the first release of *Combat Flight Simulator* lacked background and context, because the sequel, *Combat Flight Simulator 2: WWII Pacific Theater*, contains a wealth of

supporting material—even fictionalized letters from home, intended to convey some of the emotional experiences pilots had to endure. The game also has an interface reminiscent of the comic books of the period.

While *CFS 2* still offers exceptional flight modeling, the aircraft themselves have been detailed for a more weathered look: Bits of paint are flaked off wings and fuselages, and engine cowlings are smeared with oil stains. *CFS 2* also features a fully interactive virtual cockpit that is readable even when the player's view is focused outside the cockpit. But perhaps the most important improvement is the inclusion of aircraft carrier operations.



IL-2 Sturmovik. Blue Byte Software, (800) 933-2983, www.bluebyte.com, \$49.95.

Designed by Russian-based Maddox Games, *IL-2 Sturmovik* takes a hard look at the conflict fought between the Luftwaffe and the Red Air Force over the interminable eastern front of World War II. While the game is named after the Soviets' legendary tank-buster, *IL-2 Sturmovik* contains 17 flyable aircraft types, including several variants and the U.S. lend-lease P-39 Airacobra. In the case of the Sturmovik, players can either pilot the plane or turn over the controls to the computer and man the rear gunner's position. But what's interesting here is that many of the airplanes will feature different camouflage patterns, based upon seasonal changes and the sector being contested. Players will also have the ability to create and apply different types of nose art, paint schemes, and other national markings to their aircraft, so that they can signify which squadron they are flying for.

IL-2—to be released later this year—will reportedly support up to 32 players over a local area network or the Internet and can handle as many as 16 players in cooperative mode. It's not clear if two players will be able to crew any of the two-seat Sturmovik variants. *IL-2 Sturmovik* is proof positive that in the interactive arena, the East is fast catching up with the West.



1946—Hitler's Revenge. Victory Interactive. (949) 476-8874, \$49.95.

Based upon the Captain Ace Fury series of alternate-history books, *1946—Hitler's Revenge* will take a hypothetical look at what might have happened if the Luftwaffe had fielded some of the more advanced aircraft it was testing or developing at war's end. What types of weaponry are we talking about? Well there's the Natter vertical-lift-off interceptor, the Lippish P-13 jet fighter, and the Horton Ho 18 flying wing bomber, to name just a few. As players progress through the mission-based game, they will also get to pilot a manned version of the V-2 missile and close the canopy on a jet-powered Fw AS9 saucer fighter. As for the Allies, they get to slip behind the controls of some equally exotic aircraft, including the low-observable X-35 and X-71 flying wing fighters. In the simulation, the Allies have withdrawn from Europe and are preparing for a German invasion of the Eastern U.S.

Stormbird. Crosswind Simulations, www.crosswindsims.com (price unknown at press time).

Stormbird's name refers to the Luftwaffe's Me 262 Sturmvogel, of which there are five different variants depicted in the game. In addition, *Stormbird* will include a flyable version of the Me 163 Komet rocket interceptor, as well as non-flyable versions of the Ba 349 Natter, Do 335 Pfeil, and the Ho 229 flying wing bomber.



Unlike *Hitler's Revenge*, in which the player is flying for a fictitious squadron, pilots in *Stormbird* begin the game as wingmen in one of five vaunted Luftwaffe formations. Four Me 262 units have been painstakingly depicted, including JG 7, KG 51, KG 54 and JV 44, as well as the brave airmen who flew for JG 400, a unit equipped with the dangerous (to its pilots) Komet interceptor. According to Crosswind, the company plans on licensing the GTT dynamic game engine known as "Battle-Logic" from Game Tool Technologies to help create the campaign game.

—Marc Dultz is a freelance computer simulation reviewer.

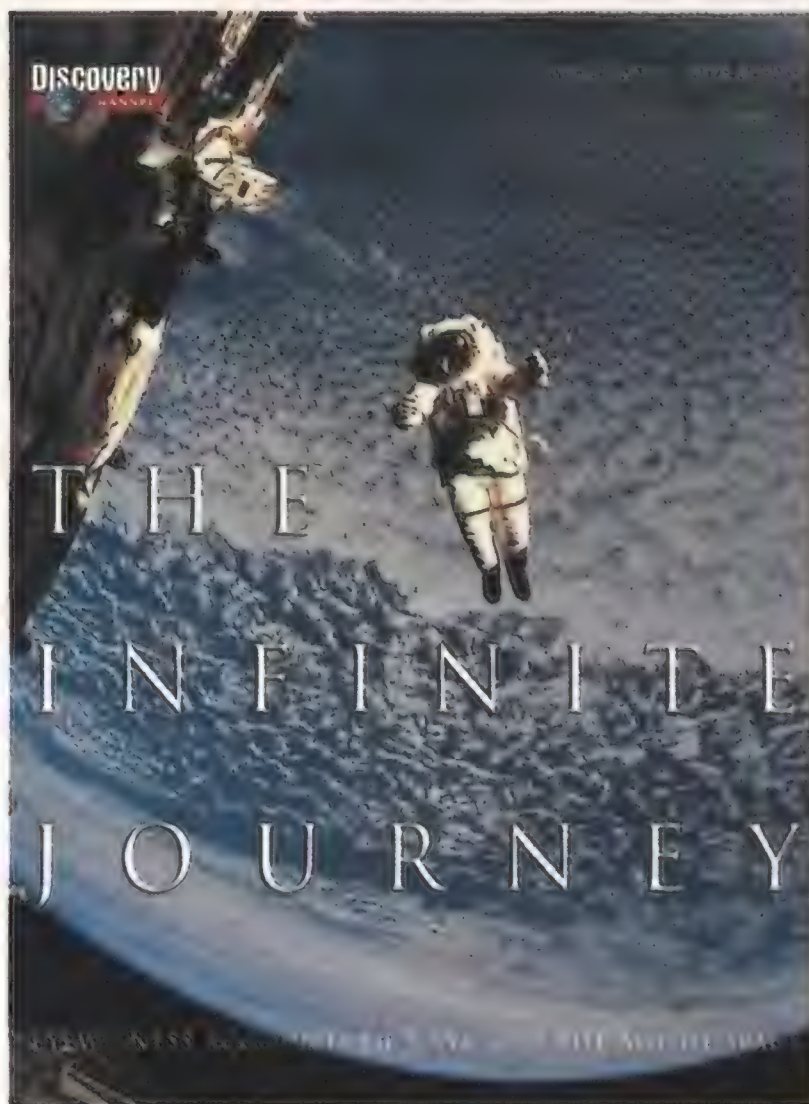
The Infinite Journey: Eyewitness Accounts of NASA and the Age of Space

by William E. Burrows.
Discovery Books, 2000. 240 pages, \$39.95 (hardbound).

Nicely paced and beautifully illustrated, *Infinite Journey* takes us from the earliest visions of rocket pioneers Robert Goddard and Wernher von Braun to the International Space Station and beyond.

We've all seen most of the photos before (although the shot of a mule-drawn plow being used to dig cable trenches for an Apollo engine test stand was a surprise), and the story of space exploration is a well-worn topic. But in the wake of recent encyclopedic treatments—including William Burrows' own *This New Ocean*—this telling is an easily digestible package centered on the original words of astronauts, engineers, aerospace workers, and even artists who were witness to both triumph and tragedy.

Burrows, an *Air & Space* contributing editor, introduces each section with a



brief scene-setter, then retreats to let the principals speak. Yes, there are descriptions of walking on the moon or seeing Earth from space for the first time. But we also hear from pilot James Holliday, who through meticulous planning with his first officer placed his airliner and its passengers in a perfect spot to enjoy a spectacular nighttime view of Apollo 8 reentering and streaking across the sky 65 miles away. Holliday banked his aircraft to follow the capsule's fiery plume while his passengers scrambled from their seats and crowded around the windows. And there are the chilling words of pararescueman Craig Kennedy, who describes watching "Volkswagen-sized" pieces of the exploding *Challenger* miss his helicopter by 50 feet and crash into the sea, and astronaut Janice Voss' brief and charming account of curling up next to a space shuttle window—not to gaze below in wide-eyed wonder, but to use Earth-light to read a book. You may wonder what author could win a competition with a view like that: Fittingly, science fiction legend Isaac Asimov.

Infinite Journey is an entertaining tour of the space program, enlivened by richly reproduced photographs and original voices.

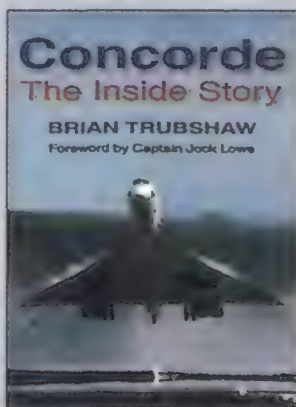
—John Sotham is an associate editor of *Air & Space*.

CONCORDE

Concorde: The Inside Story

by Brian Trubshaw.
Sutton Publishing, 2000. 176 pp., \$29.95 (hardbound).

Written by the Concorde's chief test pilot, Brian Trubshaw, this detailed look at the long career of Europe's supersonic transport contains photos and illustrations of the aircraft in production and in British Airways and Air France service. Of particular interest is Trubshaw's description of the aircraft's early flight test program. The *Inside Story* was published before the July 2000 crash of an Air France Concorde outside Paris.



SCIENCE IS ALIVE!

See it in action with these scientific, educational and entertaining products.

- Astronomy
- Telescopes
- Binoculars
- Magnets
- Optics
- Lasers
- Robots
- Physics
- Motors
- Biology
- Chemistry
- Magnifiers
- Microscopes
- Components



FREE Catalog... Over 5000 items!
Order Online or call 800-728-6999



SCIENTIFICS®

A DIVISION OF EDMUND SCIENTIFIC

Dept. A011-C801, 60 Pearce Ave., Tonawanda, NY 14150
Fax: 716-874-9572 • E-mail: cons_order@edsci.com

www.scientificsonline.com

Now Available! Air & Space/Smithsonian Slipcases!

Collect & preserve your back issues of *Air & Space/Smithsonian* in these deluxe library cases. Each case is blue with gold embossing and holds six issues—a full year of *Air & Space*!

To order: send \$7.95 per case (includes shipping & handling*) to:

Air & Space/Smithsonian 901 D Street, SW 10th floor
Washington, DC 20024-2518

*for domestic order only, international orders add \$3.00.

KITES!

Windsocks, Flags and Spinners
Traditional, Stunt and Power Kites
Free 80 page Catalog, or shop online at:

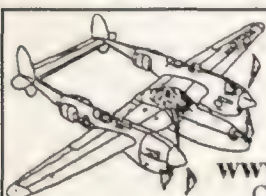
www.intothewind.com

1408-K Pearl St., Boulder, CO 80302 • (800) 541-0314



AIRLINER FAN? World's Largest

selection of airline and airliner related items: books, videos, models, calendars, shirts, magazines, etc., including our own *AIRLINERS*, The World's Airline Magazine. Call (800) 875-6711 or (305) 477-7163, fax (305) 599-1995 or write: *AIRLINERS* Catalog, PO Box 521238-AS, Miami, FL 33152-1238 USA for a free fully-illustrated color catalog.



Aviation Models

Desktop Display Models

See our on-line catalog

(800) 591-4823

www.aviation-models.com

Check out our sister website

The Aviation History On-line Museum

www.aviation-history.com

CREDITS

Jump Ship. Former U.S. Air Force Reservist E. Stuart Gregg flew as a rotary wing and fighter test pilot. He also flew combat missions with the Eighth Fighter Group in World War II before being taken prisoner by the Germans.

Body by Erco. Lester Reingold lives in Silver Spring, Maryland, near the historic College Park Airport and the adjoining College Park Aviation Museum, where two Ercoques are on display.

Don't Mess With Switzerland. Carl Posey writes novels and nonfiction articles from his home in Alexandria, Virginia.

Katsuhiko Tokunaga is a Tokyo-based aviation photographer. He has flown almost 800 hours in high-performance jets while taking pictures.

Further reading: *La Place de la Concorde Suisse*, John McPhee, Farrar, Strauss, Giroux, 1984.

Terra Cognita. Tony Reichardt is a consulting editor at *Air & Space/Smithsonian*.

The Hammer. Peter Garrison is a freelance writer living in Los Angeles. He is preparing to test-fly his second aircraft design, which he very much hopes will be flutter-free.

John MacNeill is a freelance computer graphics artist. His studio is just outside Boston.

Restoration: Desperate Journey. Douglas Hinton flew jet fighters in the Royal Canadian Air Force, then spent over 35 years in the general aviation industry, holding a number of sales and

marketing positions. He now writes from his home in central Florida.

Baikonur. John Sotham is an associate editor at *Air & Space*.

Scott Andrews has photographed over 100 manned launches from the United States and Kazakhstan. He has covered the U.S. involvement with the Russian space program, beginning with the Soyuz launch of Norm Thagard and culminating with the recent launch of Bill Shepherd and his crewmates to the International Space Station.

High Tension. James R. Chiles' book, *Inviting Disaster*, about the causes and prevention of man-machine catastrophe, will be published by HarperCollins this year.

Jeffrey Brown was a finalist for the 1997 Pulitzer Prize in Feature Photography. Says Brown: "I try to tell a story from a fresh perspective and bring back something unseen, unexpected."

What Were They Thinking? Phil Scott has two books on early aviation to his credit: *The Pioneers of Flight* (Princeton University Press, 1999) and *The Shoulders of Giants* (Addison-Wesley, 1995).

Made in the U.S.S.R. Von Hardesty is a curator in the division of aeronautics at the National Air and Space Museum and has written, edited, and translated a number of books on Russian aviation history.

CALENDAR

February 3

"Women in Aviation" Seminar. The program will conclude with a flight demonstration of a North American P-51D Mustang. Planes of Fame Museum, World War II CAL-AERO Field, Chino, CA, (909) 597-3722.

February 11–13

HELI-EXPO 2001. The world's largest trade show for the civil helicopter industry. Sponsored by the Helicopter Association International. Anaheim Convention Center and the Anaheim Marriott, Anaheim, CA, (703) 683-4646, www.rotor.com.

February 13–18

Australian International Airshow: Aviation, Aerospace, and Defence Technology for the New Millennium. Avalon Airport, Victoria, Australia, phone 61 (0)3 5282 4400, www.airshow.net.au.

March 1–4

National Warbird Operator Conference. Washington, DC, (480) 675-9322.

March 3

Fighter Aces Seminar. The program will conclude with a flight demonstration of the museum's Republic P-47G Thunderbolt. Planes of Fame Museum, World War II CAL-AERO Field, Chino, CA, (909) 597-3722, www.planesoffame.org.

Vintage Aircraft Fly-In, Aerial Photography Program, and Pancake Breakfast. Experimental Aircraft Association Chapter 690, Lawrenceville, GA, (770) 613-9501.

March 17 & 18

Air & Motor Spectacular. Sponsored by Cox Communications. Fighter jet demonstrations and monster trucks. Williams Gateway Airport, Mesa, AZ, (480) 774-9355, www.coxairshow.com.

Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, 750 9th St. NW, 7th Floor, Washington, DC 20001. Events will be listed as space allows.

ON THE WEB SITE

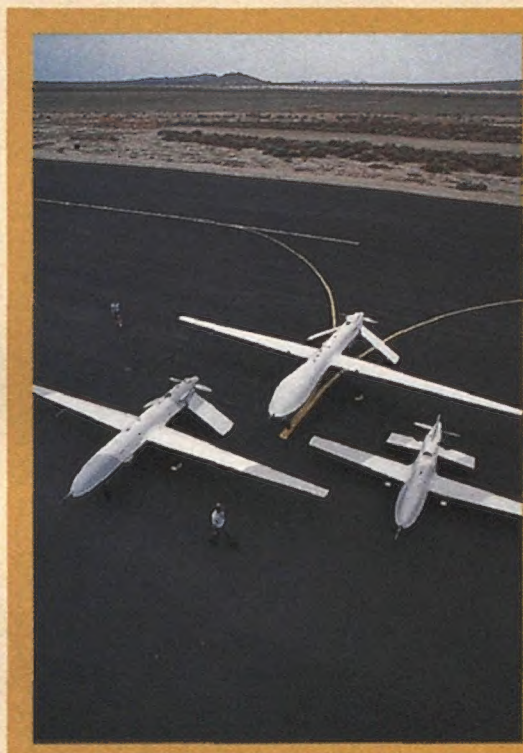
www.airspacemag.com



Flutter: The Movie

From the Transonic Dynamics Tunnel at NASA's Langley Research Center in Hampton, Virginia, three videos show the shake, rattle, and roll of aircraft undergoing flutter tests. The research center has run approximately 550 flutter tests, only one of the many types of testing done in the Transonic Dynamics Tunnel, which is now entering its 41st year of operation.

FORECAST



Family portrait: General Atomics' Gnat, Predator, and Prowler II aircraft fly pilotless.

In the Wings...

Predator Pilots

When U.S. Air Force pilots of the 11th and 15th Reconnaissance Squadrons fly a mission, they climb into a control van instead of a cockpit. How are the operators of Predator aircraft adapting to the ways of robots?

The Fastest Show on Earth

Here they come! There they go! Lockheed's F-104 "Missile With a Man in It" has hit the airshow circuit.

BONUS POSTER: Starfighter!

An affirmation—in a hyper-realistic portrait—of the F-104's star quality.

Q

Space explorers may not all be James Bond types, but they get good gadgets.

Fishing for St. Ex

What may be Antoine de Saint-Exupéry's P-38 will remain in the depths of the Mediterranean, if the aviators' descendants have their way.

Annihilation Station

With an experiment on the International Space Station, a Nobel laureate will become the first physicist to search for anti-matter in space.

Restoration: Glamour Puss

After years out of service, this Super Constellation Starliner, one of the few lovely Connies left of 856 that Lockheed built, will soon fly again.

CHAD SLATTERY

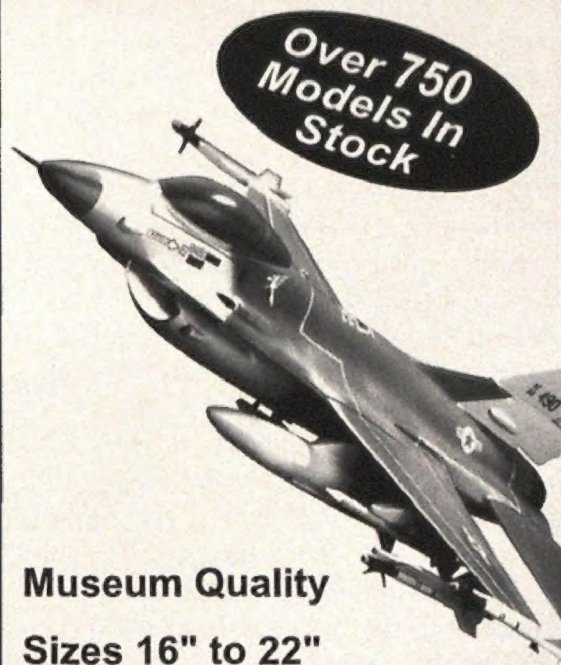
PACIFIC AIRCRAFT
WARPLANES.COM
The Collector's Choice

Makers of Fine Aerosculptures



Exquisitely
hand painted
markings & details.

Hand Carved From
Solid Mahogany



Museum Quality

Sizes 16" to 22"

Stand Included

From \$99.95



Satisfaction Guaranteed
Catalog & Orders

800-950-9944

www.warplanes.com

14255 North 79th Street
Scottsdale, AZ 85260

Tiger Beat

At the Experimental Aircraft Association's fly-in at Oshkosh in July 1999, I set a new record in Time to Climb to 3,000 Meters (10,000 feet) in the *Exxon Flyin' Tiger*, a low-wing monoplane I built solely for setting records. I started planning my next attempt to coincide with the annual fly-in I host at Flyin' Tiger Airport in Angleton, Texas. I chose the first weekend in November, the month that traditionally provides the best weather. Festivities at the 2000 fly-in, to be held on Saturday the 4th, would include a crawfish boil, helicopter rides, skydivers, flour bomb drops, radio-controlled model airplanes—and a shot at the Time to Climb to 6,000 Meters (20,000 feet) record, which for piston engine aircraft in class C-1.B (those weighing between 1,102 and 2,204 pounds) stood at 7 minutes, 14 seconds.

Things started coming unglued when I called to verify the arrival time of the helicopters I'd reserved for rides. The operator had sold the business, and all 16 helicopters were gone. Then, due to unseasonably warm weather, there were no crawfish to be had. I made a quick menu change to catfish. The day before the fly-in, we got three and a half inches of rain. I cancelled the catfish and changed the fly-in to a hangar party.

On Saturday morning about a hundred people showed up. I filed a flight plan and waited for the clouds to break. At 3 p.m., we got another inch of rain. After six hours of waiting, I called off the record attempt that day. But my guests stayed in high spirits, and the hangar party continued well into the night.

On Sunday it looked like I might get a break. My main concern was getting off—and back on—the waterlogged runway without ending up on my back. As I ran up the engine, National Aeronautic Association observer Larry Steenstry stood by the runway. I slid onto the grass strip, held the brakes, and applied power. At 9:05 a.m., before a throng of 10, I was off.

Once in the air, I checked with



RICHARD VANDER MEULEN

Houston Center, which replied, "Experimental 389 Bravo Bravo, radar contact two miles south of Flyin' Tiger Airport, leaving 7,000 feet. Climb and maintain flight level 200. Good luck!" I was cleared straight to 20,000 feet.

I made a mental note of the time as I passed 15,000 feet: 4 minutes, 50 seconds. Seeing that it took 27 seconds to reach 16,000 feet, I allowed myself a grin. At this point, maintaining a rate of climb better than 2,000 feet per minute meant the record was about to fall.

When I reached 20,000 feet, I called Houston Center, which vectored me back to the airport. I thanked everyone for their help and prepared for the scary part: landing in a marsh that a couple of days ago was a runway. I touched down on the highest point of the crown of the runway and eventually slid to a stop.

Steenstry met me at the airplane to tell me my time was 6 minutes, 37 seconds, which beat the previous record by 37 seconds. Pending NAA verification, the *Exxon Flyin' Tiger* holds all Time to Climb records in its class: 10,000, 20,000, and 30,000 feet.

—Bruce Bohannon

Moments & Milestones is produced in association with the National Aeronautic Association. Visit the NAA Web site at www.naa-usa.org or call (703) 527-0226.

LOGBOOK

Awards

Jeana Yeager received the Katherine and Marjorie Stinson Award for Achievement for co-piloting the Voyager aircraft nonstop and without refueling around the world in nine days in 1986. Spann Watson received the Cliff Henderson Award for Achievement to honor his work as a Tuskegee Airman and his lifelong commitment to the aerospace industry. Both awards were presented at the NAA Fall Awards dinner last September in Washington, D.C.

Call for Nominations

The Katharine Wright Memorial Award is given annually to a woman who has provided support and inspiration to her husband and thus was instrumental in his success, or who has made a personal contribution to the advancement of aviation or spaceflight over an extended period. Nominations are due by March 31. Contact Ann Ruebelmann at the NAA: (703) 351-2462 or aruebelmann@naa-usa.org

Certificates

Micco Aircraft has received Federal Aviation Administration certification for the SP-26, a 260-horsepower aerobatic version of the SP-20 two-seat taildragger that was awarded its certificate in January 2000. Prices start at \$199,500.

Events

National Hang Gliding Competition, Standard Class, will be held at Mifflin County Airport, Reedsville, Pennsylvania, May 15–24. Sports Class and 18-Meter Class will be held at Siskiyou Country Airport, Montague, California, July 1–12.

Records

Steve Fossett, a familiar name in NAA records, flew a Cessna Citation X around the world westbound last November 22–24. Fossett and copilots Alex Tai and Pierre d'Avenas made the 25,822-mile flight at 500.56 mph in 51 hours, 35 minutes, and 13 seconds, besting the previous record by three minutes.

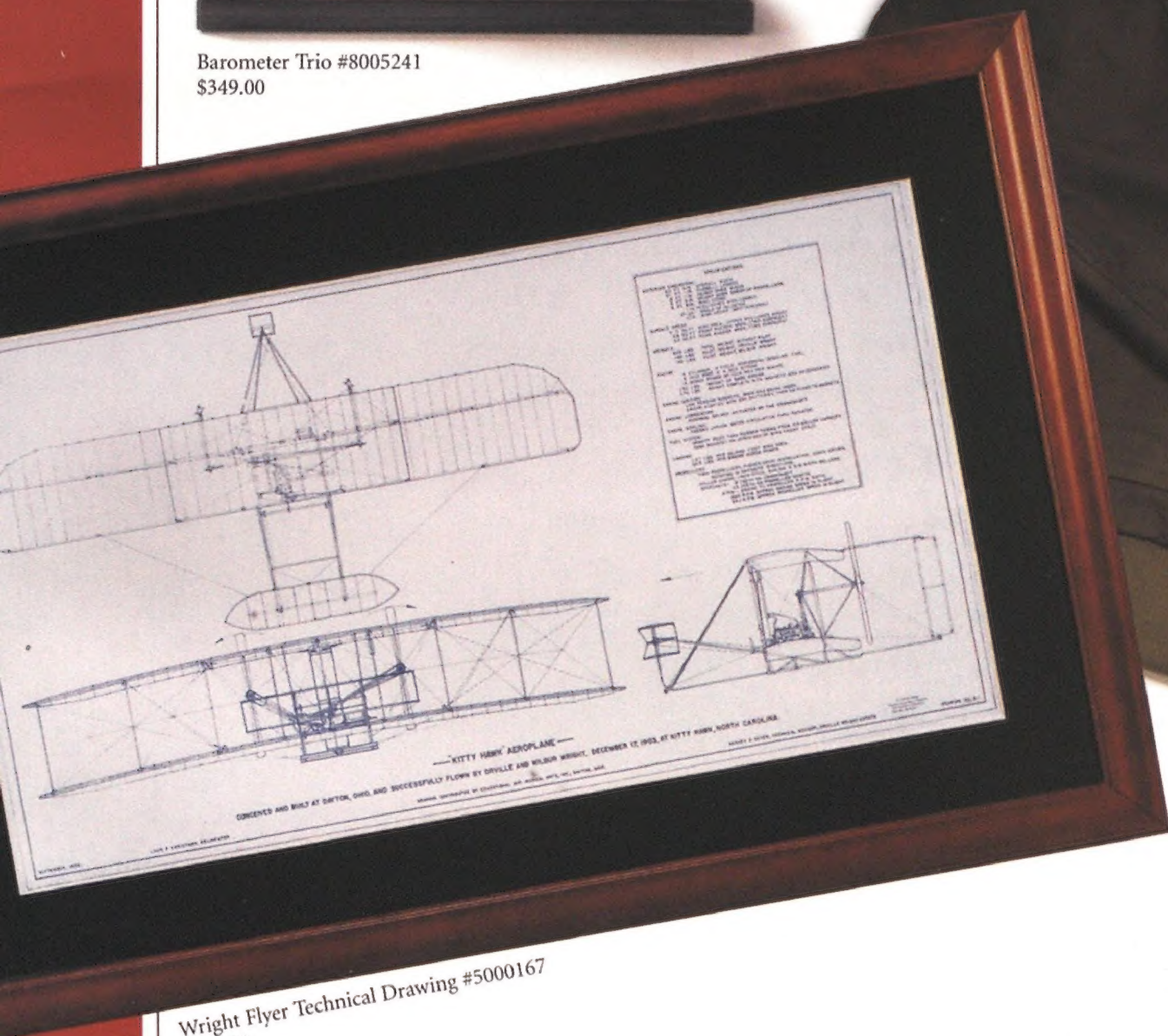


Metal Die Cast F-4 Phantom #5000344
\$95.00

Space Shuttle Bullet Pen #5000624
\$19.95



Barometer Trio #8005241
\$349.00



Wright Flyer Technical Drawing #5000167
\$175.00



Classic Leather Flight Jacket #5000167
\$198.00

[It's a guy thing.]

www.SmithsonianStore.com

Join online today. Smithsonian members get 10% off purchases at SmithsonianStore.com. A portion of your purchase benefits the National Air and Space Museum.

In association with MuseumCompany.com

**WHEN CHUCK YEAGER BECAME THE
FIRST MAN TO BREAK THE SOUND BARRIER, HE HAD
A ROLEX CHRONOMETER ON HIS WRIST.**

**FIFTY YEARS LATER, STILL WEARING
A ROLEX, HE DID IT AGAIN.**




Chuck Yeager has made a long career out of pushing the edge of the envelope by only trusting himself to the best equipment. "That's why I wore a Rolex when I broke the sound barrier," he says, "and why I still wear one today."




ROLEX

GMT-Master II Officially Certified Swiss Chronometer.

For the name and location of an Official Rolex Jeweler near you, please call 1-800-36ROLEX. Rolex, , Oyster Perpetual and GMT-Master II are trademarks. www.rolex.com